REPORT DOCUMENTA

AD-A255 474

Approved No. 0704-0188

Public reporting burden for this collection of information is estimated to ... searching existing data sources, gathering and maintaining the data needed, and completing and reviewing ... mate or any other aspect of this collection of information, including suggestions for reducing this burden ... ons and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of ... ington, DC 20503

1. AGENCY USE ONLY (Leave blank)	2. REPORT DA	...ED
	12 Jul 92	DISSERTATION

4. TITLE AND SUBTITLE

Incentive Contract Use is Military Contruction

5. FUNDING NUMBERS

6. AUTHOR(S)

Clayton K.S. Chun

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

AFIT Student Attending: RAND Graduate School

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/CI/CIA-92-10D

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

AFIT/CI
Wright-Patterson AFB OH 45433-6583

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

DTIC ELECTE AUG 31 1992 S C D

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for Public Release IAW 190-1
Distributed Unlimited
ERNEST A. HAYGOOD, Captain, USAF
Executive Officer

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

92-23926

012200 18818

92 8 28 029

14. SUBJECT TERMS	15. NUMBER OF PAGES
	186
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

01.

INCENTIVE CONTRACT USE IN MILITARY CONSTRUCTION

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This dissertation was submitted on July 12, 1992
in partial satisfaction of the
requirements for the degree of
DOCTOR OF PHILOSOPHY
in the
RAND Graduate School
Santa Monica, California

Approved:

Michael Kennedy Michael Kennedy 6 July 92
(Chairman) date

Anthony G. Bower Anthony G Bower 7/6/92
date

Lionel Galway Lionel Galway July 6, 1992
date

PREFACE

This examination of the possible application of incentive contracts for the Air Force's military construction program uses publicly available materials. The evaluation of contracting options should be of interest to the Office of the Secretary of the Air Force, particularly SAF/AQC and SAF/FM; the Deputy Chief of Staff for Civil Engineering (HQ USAF/CE); the US Army Corps of Engineers; the Naval Facilities and Engineering Command; and private construction firms. In addition, this study should be of interest to the Department of Transportation, US Postal Service, the General Services Administration, and Congressional staffs interested in construction contracting strategy and planning.

The cutoff date for data in this report is December 1991.

ACKNOWLEDGEMENTS

I want to thank my dissertation committee for their encouargement, patience, and guidance. My committee chairman, Michael Kennedy, and other members, Lionel Galway and Tony Bower, provided constructive criticism and continued encouragement throughout my research.

The United States Air Force provided generous financial support while I completed my coursework and dissertation. I would like to thank two former colleagues, Lieutenant Colonel Robert Waller and Lieutenant Colonel Terry Raney, for their support in pursuing this degree and their valuable advice.

I want to acknowledge publicly the support I received at home from my wife, Cheryl, and son, Douglas, throughout my research.

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ACRONYMS

ACO	Administrative Contracting Officer
AFAA	Air Force Audit Agency
AFB	Air Force Base
AFIT	Air Force Institute of Technology
AFP	Air Force Pamphlet
AFR	Air Force Regulation
AGC	Associated General Contractors of America
AFRES	Air Force Reserves
AFSC	Air Force Systems Command
AIA	American Institute of Architects
ANG	Air National Guard
ASPR	Armed Services Procurement Regulation
ATC	Air Training Command
CCMAS	Construction Cost Management Analysis System
CE	Deputy Chief of Staff, Civil Engineering
COE	Corps of Engineers
CPIF	Cost Plus Incentive Fee contract
DCAA	Defense Contract Audit Agency
DD	Defense Department
DoD	Department of Defense
DSMC	Defense Management Systems College
ECIP	Energy Conservation Investment Program
ELM	Elaboration Likelihood Model
EMCS	Energy Management and Control System
FAR	Federal Acquisition Regulations
FFP	Firm Fixed Price contract
FM	Directorate of Financial Management
FPI	Fixed Price Incentive contract
FY	Fiscal Year
GAO	General Accounting Office
GFE	Government Furnished Equipment
HQ USAF	Headquarters, United States Air Force
ICBM	Intercontinental Ballistic Missile
IFB	Invitation for Bid
MILCON	Military Construction
MAJCOM	Major Command
MH	Moral Hazard
NASA	National Aeronautics and Space Administration
NAVFAC	Naval Facilities and Engineering Command
O&M	Operations and Maintenance
OSD	Office of the Secretary of Defense
PCO	Procuring Contracting Officer
PDC	Program, Design and Construction database
RFP	Request for Proposal
SAF	Office of the Secretary of the Air Force
SBA	Small Business Administration
SOP	Standard Operating Procedure

TOA	Total Obligational Authority
USC	United States Code
8(a)	Section 8(a) SBA award, sole source award
8(d)	Section 8(d) SBA award, competed award

I. INTRODUCTION

In this study, I examine whether the Air Force can reduce its contract payments for military construction by using incentive contracts. I use an optimal contract model to evaluate the use of incentive contracts in the Air Force's military construction program.[1] By using this optimal incentive contract model, I calculate the expected contract payments from data from actual contract cases.

The use of incentive contracts in construction may affect the Air Force's present contracting system program in three ways. First, incentive contracts may reduce the Air Force's military construction contract payments relative to the current contracting system. Lower contract payments are important to the Air Force in light of declining defense budgets. Second, the increased use of incentive contracts can provide an additional contracting tool for government contracting officers in military construction acquisitions instead of exclusively relying on firm fixed price (FFP) contracts. The Air Force uses FFP contracts in over 99 percent of its military construction contract awards.[2] Third, the Air Force and Department of Defense (DoD) can extend the use of incentive contracts to other non-weapon systems acquisitions (the DoD awards most of its fixed price incentive contracts to weapons production activities).[3] Very few non-weapons programs involve incentive contracts. If incentive contracts save money for the Air Force on military construction, the DoD could also use this contract type on these other programs.

This chapter includes a discussion of military construction and the study methodology used to examine the possible application of incentive contracts. Specifically, this chapter describes why the Air Force wants to reduce the payments on military construction programs and some recent

1. I use the terms "fixed price incentive contract" and "incentive contract" interchangeably in this dissertation.
2. Data from the Air Force Program, Design, Construction database, 3 Jan 1991.
3. See McAfee and McMillan 1985(b), Incentives in Government Contracting, p. 7-11.

attempts to accomplish this goal. A study design follows this discussion with an emphasis on how to model, select data, and analyze the problem. Finally, the chapter concludes with a preview of future chapters.

1.1 THE AIR FORCE MILITARY CONSTRUCTION PROBLEM

The Air Force faces many pressures to improve its military construction program. In this section, I identify some problems the Air Force must face to build facilities. The section also describes some recent legislative measures the federal government has used in an attempt to reduce contract payments for military construction projects.

1.1.1 MILITARY CONSTRUCTION PROBLEMS

In the future, the Air Force will face many new requirements to provide facilities. First, the reduction in Air Force bases worldwide has forced the consolidation of many units, which will need new facilities to house weapon systems and personnel. Second, the Air Force needs facilities to house new weapon systems (i.e., the B-2 bomber) entering operational status. Third, base closures have increased the need for additional environmental clean-up projects to convert the bases over to civilian use. Fourth, the Air Force will see an increased demand for the alteration or replacement of numerous facilities built in the 1950s and 1960s.

However, the Air Force will encounter many challenges in procuring new facilities. The most important challenge to buying facilities is the shrinking defense budget. The Air Force's overall budget fell 8 percent from FY90 (fiscal year 1990) to FY92.[4] This means the Air Force will have fewer resources to build facilities as its requirements increase. This

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4. See Air Force Association, "The US Air Force in Facts and Figures," p. 41.

puts much pressure on the Air Force to find ways to reduce its contract payments for military construction.

1.1.2 RECENT LEGISLATIVE MEASURES

The Air Force has recently tried to reduce contract payments on its military construction progr ω. These efforts include an array of initiatives such as build/lease arrangements and the increased use of privatization of Air Force services. Specifically, the Congress approved legislation to allow the Air Force to sign long term leases with firms for facilities. The Air Force also has tried to promote the privatization of services, in part, to reduce the need for new military construction projects. Unfortunately, these efforts have had only a limited effect on improving the acquisition of facilities.

The Air Force has used several build/lease programs authorized under the FY 1989 Defense Authorization Act to reduce contract payments. One of these programs was the Long-Term Facilities Contract (10 U.S.C. 2807), which allowed the Air Force to enter into 32 year lease contracts with firms to construct and provide facilities. The Air Force, after contract completion, can either renew the lease or require the firm to remove the facility. A related piece of legislation allows for the lease and eventual purchase of facilities (10 U.S.C. 2812), which allows the Air Force to lease a building for 32 years and obtain facility ownership at the end of the contract. This program seems similar to commercial automobile or home lease/buy contracts. By the end of FY89 these programs included 54 active projects with an estimated total dollar value of $1.2 billion (including military family housing projects).[5]

The Air Force also has privatized or "contracted out" services previously conducted by federal civil service or uniformed military personnel. Frequently, the Air Force requires the civilian contractor to provide personnel, equipment, and facilities to meet contract

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5. Interview with Headquarters United States Air Force Deputy Chief of Staff for Logistics and Engineering, 3 Jan 1991.

requirements.[6] This program can reduce facility requirements. For example, a civilian firm provides civil engineering support for the maintenance of military family housing units at Los Angeles AFB. This firm provides off-base facilities for its personnel and equipment.

These initiatives have several problems, discussed below, that may preclude their increased use throughout the Air Force. The build/lease program will take time to analyze, payments "lock in" the Air Force for long time periods, and some people consider these programs budget ploys. The privatization effort also creates problems. Some Air Force officials may believe that the military has become too "civilianized" due to privatization. Additionally, the Air Force may have indirectly paid for a firm's facilities through the services contract. The following descriptions provide more detail about these problems.

The Air Force's experiment with build/lease projects will take years to analyze and evaluate. The Air Force may have to wait up to 32 years before it can completely analyze the effects of this program. The analysis of the program results will take too long to affect contracting actions today.

Additionally, these leasing arrangements also "lock in" the Air Force to using limited operations and maintenance funding for contract payments for many years. In the last few years, the Air Force has reduced operations and maintenance funding to balance DoD budgets since these funds normally do not involve long term contracts or commitments. These reductions represent quick "savings" in the defense budget. However, the Air Force purchases spare parts, ammunition, fuel, and other goods from this account. Reduced funding and long term lease contract commitments could adversely affect these purchases and ultimately degrade operational readiness.

Some critics of these build/lease arrangements also argue that these efforts are just budget ploys. They claim the Air Force has shifted funds from facility procurement accounts to build/lease projects to reduce the high initial acquisition cost in exchange for potentially higher lease

6. Interview with an Air Force contracting officer from Los Angeles AFB, CA, 5 May 1992.

payments throughout the contract's life. The lease payments may actually cost the Air Force more than a one-time purchase of the building. These long term leases also limit Air Force options to redeploy units or close bases unless it buys out its lease.

Privatization efforts also have problems. In recent years, the Air Force has converted many base civil engineering, security, and logistics functions, once held by civil servant or uniformed military personnel, to private contractors. If Air Force units must deploy overseas, they may not have the necessary support services because the Air Force might not be able to send the civilian contractors overseas. This may degrade operational readiness due to the lack of logistics or other support. Also, unions who represent civil servants may protest this action because of job losses.

Finally, although the Air Force avoids building or renovating facilities by privatizing services, it could be indirectly paying for contractor facilities. A firm probably would capitalize any facility construction costs or include facility rents under a bid for the service contract award. Instead of paying for a facility, the Air Force pays a firm to build or rent its own facility via the services contract. This process may not save the Air Force any money.

1.2 STUDY DESIGN

In this section, I provide the methodology for my study. This examination includes a discussion about the optimal contract model used, the data requirements and acquisition, data analysis, simulation of incentive contract results, and proposals for the implementation of incentive contracts.

1.2.1 MODEL SELECTION

Why use a model? A simple strategy to compare contract types would entail a statistical analysis between FFP and incentive contract types.

This would succeed if military construction contracts included many different contract types. Unfortunately, the military construction contracting system relies primarily on FFP contracts. The remaining contract types in military construction are too few for a statistical analysis. Also, contracting officers may have specifically used these contract types due to the project's unique character. These actions could introduce bias into any statistical comparison.

An alternative might involve contract data from similar private or state projects to compare Air Force contracts. The problem with this approach is accessibility and comparability. First, not all private firms want to release contract cost information on current or past projects for study. Second, many Air Force military construction contracts have more stringent building requirements than similar private projects. Finally, an informal poll of state government public works organizations (i.e., California, New York, Minnesota, Texas, and Alabama) found that they all bid competitively with FFP contracts. This precludes state government comparisons between actual FFP and incentive contract use.

These considerations led me to use modeling to simulate incentive contracts. Although these models can only simulate potential results and trends, they do allow me to experiment with many contract alternatives without running expensive and time consuming controlled experiments. Modeling also lets me vary certain factors to conduct a sensitivity analysis on these results.

I chose a model developed by R. Preston McAfee and John McMillan for my study. I selected this model for several reasons. First, this model calculates expected contract payments under an incentive contract. These calculations do not require any extensive modifications of the Air Force military construction data. Second, McAfee and McMillan have used this model to estimate payments on construction projects for the Canadian government. Third, this model provides information on optimal share rates that can help the Air Force to establish policies for future incentive contract applications. Fourth, it provides an analysis of certain effects on bidder behavior produced by incentive contracts. This allows us to understand the relationship between optimal share rates and incentive

contract payments. Fifth, their model is very similar to the fixed price incentive contract authorized for use within the federal government by the Federal Acquisition Regulation (FAR).

McAfee and McMillan model the process of bidding on contracts in the face of moral hazard, risk sharing, and bid competition effects. Their model estimates an optimal share rate that a government contracting officer can propose to the bidders who then consider this in their bids and subsequent contract performance. The model examines these bidder actions and how it affects the expected contract payments. The McAfee and McMillan model examines how these expected payments change in relation to the number of bidders, cost padding efforts, risk aversion, expected cost variances, and other influences.

For this model, I assume that the basic construction methods and project types will not change in the future. The bidders for construction contracts in the future will face many of the same technical construction issues they must solve today. Therefore, if the incentive contract model produces savings, I have a stronger case to apply this contract type to similar construction projects in the future than using firm fixed price contracts.

1.2.2 DATA REQUIREMENTS

The universe of interest for my research includes all military construction projects in the United States (except military family housing projects) completed for the Air Force during peacetime. These military construction projects include active, reserve, and Air National Guard facilities. These projects include permanent facilities and utilities, but not temporary or mobile structures.

I use the individual project contract files as my units of analysis. Each project contract file contained many important attributes such as estimated costs, project type, contract award type, bid amounts, and other data. This allowed me to examine bidder behavior and costs in the current FFP contract setting.

I developed the specific data requirements with help from contracting officers, civil engineers, and comptrollers in the DoD, Air Force, and other federal agencies. I then used this data to describe the current system and used this same data to model incentive contracts and simulate certain contract situations. This allowed me to compare contract payments while holding many factors constant.

The desired data elements include: (1) number of qualified bidders making a bid; (2) amount of bids; (3) location of project; (4) project type; (5) fiscal year authorized; (6) contract type; (7) contract award method; (8) Air Force project cost estimate and; (9) contract modifications made by bidders and the government contracting officer after contract award.

1.2.3 DATA SOURCES

There are several potential data sources, including individual bidders, commercial sources, the Associated General Contractors of America, and the Air Force. Each source has its unique benefits, and, also, its drawbacks.

Bidder data sources can provide actual audited cost, expected costs, and profit for a contract. The bidders also can furnish information about the Air Force facility specifications, contract, and bid information. This type of information can provide an accurate picture that explains why bidders bid certain amounts. Unfortunately, the bidders may not want to release their bid data. These firms may fear that competitors might figure out how they bid if the data is publicly released and that this disclosure may cause them to lose future contracts. Gathering all the bidder information on an individual contract also takes much time and effort. One has to determine which bidders bid on a particular contract, and all the bidders have to provide the bid information to find the order of bids. Lastly, some bidders may have merged with other firms or left the construction business. This makes data collection difficult. These problems tend to rule out data collection from this source.

Another potential data source includes commercial data collection services. The F.W. Dodge Data Services construction database, a commercial source, contains very limited data regarding military construction contract data. Thus, this database may not allow one to compare many unique military construction activities and projects. Also, F.W. Dodge charges $20,000 a year to access their database. This makes the database cost prohibitive for this study.

The Associated General Contractors of America (AGC) maintains a limited database on member bids for particular contracts. The AGC is a national organization of building contractors. They require state and local chapters to maintain a database of bid information on projects. Unfortunately, members volunteer the information, and the AGC lacks a standard data management method to store and record these bids. Only Illinois, Mississippi, New York, and a few local chapters maintain their databases to include the appropriate data for this study. Also, I might not be able to verify bids because of the voluntary disclosure of this data. This brings into question a problem of systematic bias. Certain bidders may not consistently or accurately disclose their bids. In any case, the AGC was not amenable to allowing me access to their data.

The last source is the Air Force itself. The Air Force can provide the data from two areas that include the actual contract files and a computer database.

The Air Force maintains the actual contract files on all their projects regardless if the Air Force, Army, or the Navy manages the project. The Air Force does not maintain a centralized contract file depository for construction projects (neither do the Army or Navy). This means I must visit up to 102 major and 107 minor Air Force installations in the United States and its possessions to get the data. I can either take a sample or survey all bases. I might not even know how many contracts are in the universe of interest to draw the sample.

The second area involves a computer database. All three services maintain standardized computer records for their military construction contracting projects. The Air Force database, the Program, Design, and Construction database (PDC), includes the required data for the study.

The use of the PDC allows a more efficient and effective way to collect the data. Additionally, it also offers a way to gather more consistent data since it uses a standard data structure.

1.2.4 DATA COLLECTION

I collected computer records for all completed Air Force military construction (except military family housing) projects in the United States from FY80 to FY89. The PDC keeps records from 1979 to the present. Most contracting officers I interviewed said that they normally keep contract files for ten years and then put them in permanent warehouse storage or destroy them. I wanted to verify the PDC data with original documents. Therefore, I use the population of PDC contract file records from FY80 to FY89.

I retrieved the data from the PDC with the help of the Headquarters United States Air Force Deputy Chief of Staff for Logistics and Engineering's (now Headquarters United States Air Force Office of the Civil Engineer) data services division (HQ USAF/LEED) at Bolling AFB, DC. I gathered 1367 computer records that included completed contracts during the summer of 1990. I did not include all contracts started in FY89 or late FY88 since some of these contracts were not complete. However, I do have complete construction projects for all other years in the study. Contract file records contained data elements representing bid and estimated cost values, other quantitative data, and descriptive information related to the individual projects.

I conducted a simple random sample of 137 contracts to see how accurately the PDC records reflect the actual contract data. This sample includes the actual contract files from the local contracting organization awarding the contract. The contracting officers from these organizations provided data such as the number of bidders, bid amounts, and other information. The contracting officers did not find many errors in the PDC data. The main problems center on transposition errors in the lowest bid cost data element. I found two transposition errors in the 137 contracts

with a total value of $100. The data seems to represent the actual results very well.

The data records include the following data elements:

1). Program Year: The fiscal year in which the Congress approved the project. This represents the fiscal year that the Congress authorized and appropriated funds. This data element becomes useful to make present value calculations to make bid data comparable within the ten year span of construction contracts.

2). Number of Bidders: This element includes the number of bidders who submitted a bid.

3). Basic Government Estimate Award: This data element is the Air Force cost estimate for the construction project. This estimate includes not only the estimated contract cost, but an amount for administrative and overhead expenses of 5 percent of the estimate. For this data set I removed this expense. This provides a benchmark to compare bids.

4). Contract Award: Contract award represents the amount of the winning bidder's bid.

5). Lowest Bid: Lowest bid received.

6). Second Lowest Bid: Second lowest bid received.

7). Highest Bid: Highest bid received.

Non-quantitative contract characteristics gathered from the FDC included several data elements. I use this data to examine if a particular characteristic affects bidder behavior. These data elements represent:

1). Base: Location of proposed project.

2). Program Type: This data element shows whether the project is a military construction, non-appropriated funded, or military family housing program. I use only military construction projects that involve new construction of facilities.

3). Project Number: Air Force project number for the facility project. This allows me to validate the FDC data by tracing the project back to its original base.

4). <u>Project Type</u>: This data element provides an Air Force classification for the project. This allows for a distinction between different types of projects that may include varying levels of cost and technical risks for the firm. The Air Force uses eight major project type categories:

Category	Description
100	Operations related (e.g., runways or hangars).
200	Maintenance and Logistics repair.
300	Research and Development.
400	Storage and Warehouse.
500	Medical and hospital projects.
600	Administrative and computer.
700	Living and personnel support.
800	Utilities, energy projects, and roads.

5). <u>Contract award method</u>: How the government competed the contract. The government could have openly competed the contract using an invitation for bid, a sole source competition, or a small business set aside.

6). <u>Modifications</u>: Indicator value for government, contractor, or unknown source for contract modification.

7). <u>Contract Type</u>: This data element allows one to figure out if the contract was FFP or another contract type. Almost all contracts had FFP contracts.

1.2.5 DATA ANALYSIS

I use different methods to compare the data between the current system and model simulation results. I first provide a summary description of current military construction projects. Many of these comparisons involve data categorized into areas of interest to Air Force

civil engineers and contracting officers. Since these individuals have a great impact on the possible application and acceptance of incentive contracts, an analysis using these selected characteristics may allow a better understanding among these individuals concerning the simulation results. This data analysis also provides a background on military construction contracts and a baseline to compare results from the model simulations. This analysis on current military construction contracts may also provide information that I can use to identify factors that may affect bidder behavior.

This study does not use gross cost differences. Different project types might not be comparable due to scaling effects from large differences in the government estimated cost. Therefore, I compare contracts by using simple ratio analysis. For example, I calculate the percentage differences between the lowest bid and government estimated cost. This provides a measure to show variability between bids and estimated costs.

I also compare differences between current contracting practices and potential model simulations by ratios. I use simulation results to compare whether incentive contracts reduce the project payments relative to FFP contract payments by looking at savings rates. I compare these savings rates by different contract characteristics such as: project type, contract award method, geographic location of award, and other factors.

1.2.6 MODELING INCENTIVE CONTRACTS

This study uses the collected data to simulate hypothetical incentive contract results using the McAfee and McMillan model. The model then calculates the optimal share rate that minimizes the Air Force's military construction contract payment. I use these optimal share rates to determine, via the model, the expected Air Force contract payments and then compare these hypothetical contract payments to the actual FFP contract data as described earlier. I also vary certain values in the model to compare how estimated payments and optimal share rates change.

1.2.7 IMPLEMENTATION ISSUES AND POLICY RECOMMENDATIONS

The study concludes with a recommendation about the possible implementation of the incentive contract in the military construction program. I first select a way to implement the incentive contract. This involves comparing the contract award methods by estimated savings rates and other criteria. Additionally, I identify the various actors, both federal government and private industry, affected by the use of incentive contracts in military construction. Finally, this study explains certain effects of using incentive contracts.

Although the use of incentive contracts may indicate relative savings in military construction projects, I must consider how the Air Force will actually award incentive contracts. I identify and evaluate several proposals ranging from the use of the current incentive contract award method to the use of a menu of contracts.

Before the federal government starts to use incentive contracts in military construction, it must consider how this change affects particular actors. Certain federal government and private industry actors may have to change their behavior to use incentive contracts. I interviewed government and private contracting officers, construction firms, contract policy directors, and civil engineers to get their insights on a possible contract change. These opinions help me to understand any potential obstacles and to identify methods to overcome them.

Lastly, I consider the policy implications involved in the use of incentive contracts. If incentive contracts reduce Air Force contract payments and save money, how will this affect the federal government and private firms? Certain firms, like small and disadvantaged businesses, may lose profits (they also have a reduction in the risk of cost overruns) and could be driven out of business. This may result in changes in the law or service procurement regulations. Perhaps the federal government can apply this contract type to non-DoD federal organizations. Also, the DoD might apply this contract to different projects other than military construction.

1.3. A PREVIEW OF FOLLOWING CHAPTERS

This study contains six chapters. This chapter has provided a brief introduction concerning the issue of incentive contract use and its possible application to military construction. It also introduced the study design. Chapter II examines how the federal government contracts for products and services. This chapter describes the process that the Air Force uses to acquire facilities. Chapter III includes a general data analysis of Air Force military construction contracts from FY80 to FY89. Chapter IV explores the McAfee and McMillan model and its application to the Air Force military construction program. Chapter V analyzes the results of the simulation. In Chapter VI, the study examines the possible implementation schemes to apply incentive contracts in military construction.

II. FEDERAL CONTRACTING POLICY

The DoD has developed a complex set of regulations and policies concerning contracting for goods and services, which are described in this chapter. These regulations and policies govern the acquisition of military construction projects. In this chapter, I first examine the contract types available for use by the federal government. Next, I review the history of military contracting policy. Finally, I describe the Air Force's military construction contracting policy and how it awards a military construction contract to a firm.

2.1 CONTRACT TYPES

The federal government uses two major contract types, and several additional minor contract types to acquire goods and services. The two major contract types are fixed price and cost reimbursement (also known as cost plus) contracts. I provide a description of these two major contract types in this section. Next, I describe the additional contractual types that the federal government allows a contracting officer to use in lieu of the fixed price or cost plus contract. I also discuss contract progress payments. Finally, I discuss the regulations governing contract awards to small and disadvantaged businesses.

2.1.1 FIXED PRICE CONTRACTS

The federal government prefers that its contracting officers use fixed price type contracts.[1] The DoD has awarded 75 percent of its total contracts using fixed price contracts in the past decade (this represents

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1. See Air University, Contract Administration Volume I, p. 22.

about 62 percent of the total dollar value of contracts).[2] The contracting officer can use several different types of fixed price contracts, which vary according to the amount of risk a firm assumes for cost overruns on the project. Some fixed price contracts assign all risks to the firm, while others allow a sharing of risk between the federal government and the firm. The firm's payment does not change if it assumes all risk of cost overrun. Conversely, the firm's payment can vary if the federal government shares the cost overrun risks with the firm. This contract type uses a price ceiling on the maximum government contract payment.

2.1.1.1 THE FIRM FIXED PRICE (FFP) CONTRACT

The federal government pays a single predetermined price to a firm for a good or service under the FFP contract. This contract is easy to award and administer. The DoD awards an average of 56 percent of its total contract awards with FFP contracts (this represents about 40 percent of the total dollar value of contracts).[3]

Normally, the contracting officer selects the contract awardee from a pool of competing firms based on their bids, using a first price sealed bid auction (also called a first price sealed bid award). The contracting officer allows firms to make a single bid for the contract award. The contracting officer then opens the bids publicly on a prearranged date, determines the lowest bid, and awards the contract to the firm with the lowest bid (b). The contracting officer must ensure that the winning firm's b is less than a predetermined price ceiling (p). The value of p is the budgeted amount for the project approved by the Congress and administered by the federal agency. If b is greater than p, the contracting officer can compete the contract again. The federal government's payment (τ) does not vary with the firm's cost performance and changes only if the contracting officer modifies the existing

2. See Office of the Secretary of Defense, Prime Contract Awards, various pages.
3. Ibid.

contract. The federal government pays the firm only the bid amount at the completion of the project. Therefore, the contract's payment is:

$$\tau = b. \tag{1}$$

Where:

$$b \leq p.$$

Let C equal the actual cost incurred by the firm; the firm's profit is then b - C. Each additional dollar saved by reducing actual costs becomes an additional dollar of profit for the firm. Thus, the firm has great motivation to reduce its actual costs.

2.1.1.2 THE FIXED PRICE INCENTIVE (FPI) CONTRACT

An FPI contract adjusts τ according to a formula based on the difference between b and C. The contracting officer establishes a share rate (α) that acts as an adjustment device to increase or decrease τ based on the firm's cost performance. This α value is the percentage that the federal government shares in cost overruns and underruns with the contractor. This adjustment reduces τ for a contractor if C is less than b. Conversely, the contracting officer increases τ if C exceeds b. The lowest bid wins the award like the FFP contract award. The contracting officer also must ensure b is less than p. If b is greater than p, the contracting officer will re-compete the contract. The contracting officer also informs the winning bidder that τ will not exceed p.

The government contract payment is:

$$\begin{aligned} \tau &= b + \alpha(C - b) && \text{if } b + \alpha(C - b) < p, \\ \tau &= p && \text{if } b + \alpha(C - b) \geq p. \end{aligned} \tag{2}$$

The challenge for the contracting officer revolves around the selection of the optimal share rate, α. Firm behavior changes depending of the value of the share rate. If $\alpha = 0$, the contract is an FFP contract. A value of $\alpha = 1$ makes the contract a cost reimbursement contract. Chapter IV includes a method to calculate the optimal α.

The contracting officer must consider the firm's actual costs to determine τ. This means the contracting officer needs an accurate auditing of costs to determine the proper value of τ.

Currently, the DoD closely follows the FAR guidance regarding incentive type contracts. According to the FAR, the contracting officer can use an FPI contract when all the following conditions apply:

"1). A firm fixed price contract is not suitable;

2). The nature of the supplies or services being acquired and other circumstances of the acquisition are such that the contractor's assumption of a degree of cost responsibility will provide a positive profit incentive for effective cost control and performance; and

3). If the contract also includes incentives on technical performance and/or delivery, the performance requirements provide a reasonable opportunity for the incentives to have a meaningful impact on the contractor's management of the work."[4]

Additionally, the FAR requires that a contracting officer can only use an FPI contract after a determination and findings board decides that any other contract type is more costly than an incentive contract or that the federal government cannot obtain the goods or services by any other contract type. The contracting officer convenes the determination and findings board. The board is composed of contracting officials, staff judge advocate generals, comptroller, project engineers (if appropriate), and other interested parties. This board can take weeks to determine if the contracting officer can use the FPI contract. Therefore, the contracting officer cannot unilaterally select the use of an FFP contract.

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4. Ibid, Sec. 16.403.

2.1.2 COST REIMBURSEMENT CONTRACTS

The federal government also can use several types of cost reimbursement contracts. Cost reimbursement contracts account for about 24 percent of all DoD contract awards. This represents about 37 percent of the total DoD contract dollars. With these contracts, the federal government reimburses all costs incurred by a contractor up to a given price ceiling. The application of a cost reimbursement contract also requires approval by a determinations and findings board. The contracting officer normally uses cost reimbursement contracts when "uncertainties involved in contract performance do not permit costs to be estimated with sufficient accuracy to use any type of fixed price contract."[5] The "contract performance" involves the firm's delivery of the desired good or completion of the service as specified in the contract's requirements. For example, the Air Force awards cost reimbursement contracts to build experimental aircraft. These contracts also require a cost audit to calculate the correct τ like the FPI contract. Cost reimbursement contracts for military construction projects have additional requirements that are discussed later.

2.1.2.1 THE COST PLUS FIXED FEE (CPFF) CONTRACT

In the CPFF contract, the contractor faces minimum risk of cost overrun (unlike an FFP contract). The DoD awards 23 percent of all its contracts (35 percent of its contract dollars) with CPFF contracts. The CPFF contract requires the contracting officer to reimburse the firm for all legitimate expenses up to p. The contracting officer and the firm agree on a fixed fee that the contractor will receive for its contract performance. The predetermined fixed fee (f) does not vary with the amount of costs incurred by the firm, and thus provides little incentive to reduce costs.

The government's contract payment is:

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5. Ibid, Sec. 16.301-2.

$$\tau = C + f \qquad \text{if } C + f \le p,$$

$$\tau = p \qquad \text{if } C + f > p. \tag{3}$$

The contracting officer selects the winning bidder based on such factors as the firm's technical proposal and "bid." The "bid" includes only the firm's estimated cost to complete the contract since the fee is negotiated. The contracting officer uses weighted criteria to evaluate each bidder's proposal based on technical feasibility, past contract performance, and bid. In addition, the contracting officer uses functional experts to evaluate and "score" each proposal. The firm that scores the highest, under these weighted criteria, wins the contract. The lowest bidder does not always win the contract award.

2.1.2.2 THE COST PLUS INCENTIVE FEE (CPIF) CONTRACT

The contracting officer also can use a CPIF contract (these contracts represent 1 percent of DoD contract awards and 2 percent of contract dollars). The contracting officer selects a bidder like the CPFF award. However, a CPIF contract provides for a negotiated minimum (f_{min}) and maximum (f_{max}) fee adjusted by a formula based on C and the winning bid (b_w). The federal government reimburses the firm for all allowable costs and any fee up to p. The value of the CPIF actual fee, f_c, depends on the value of f_{min}, f_{max}, C, b_w, and a share rate, α.

The project f_c is:

$$f_c = (1 - \alpha)(b_w - C) + f_{min} \qquad \text{if } f_{min} < [(1 - \alpha)(b_w - C) + f_{min}] < f_{max},$$

$$f_c = f_{min} \qquad \text{if } [(1 - \alpha)(b_w - C) + f_{min}] \le f_{min},$$

$$f_c = f_{max} \qquad \text{if } [(1 - \alpha)(b_w - C) + f_{min}] \ge f_{max}. \tag{4}$$

The τ is:

$$\tau = C + f_c \qquad \text{if } C + f_c \le p,$$
$$\tau = p \qquad \text{if } C + f_c > p. \tag{5}$$

The firm must not incur an estimated τ (i.e., $C + f_c$) that exceeds p unless directed by a contracting officer. In fact, the firm must notify the contracting officer when it reaches 75 and 85 percent of the price ceiling. This allows the contracting officer to analyze and possibly terminate the firm's contract (called the Limitation of Cost Clause).[6]

The FAR allows firms to collect an amount equal to f_{max} according to limits set forth in the Armed Services Procurement Act of 1947 for cost reimbursement incentive contracts. Most contracts have maximum fees that do not exceed 10 percent of the firm's bid. The FAR does allow the contracting officer to adjust the "10 percent" maximum fee based on the nature of the contract work. The contracting officer can increase this rate to 15 percent if the work appears experimental in nature. Conversely, the contracting officer must limit this rate to 6 percent if the work deals with architectural and engineering designs or construction work.[7]

2.1.3 OTHER CONTRACT TYPES

The contracting officer also can use one of three additional minor contract types. They represent less than 1 percent of contract awards and total DoD contract dollars. These additional contract types include the binding commitment, the letter contract, and the time and materials contract. These three minor contract types are used in very rare procurement situations.

In some cases, the contracting officer might not know the final quantity of a particular product required, yet he needs to have a "binding

6. See Air University, Contract Administration Volume I p. 25.
7. Ibid, p. 25.

commitment" with a contractor. This binding commitment requires the contracting officer to pay a firm for any services rendered to the federal government. For example, the Air Force may want to ensure a particular airport provides fuel and aircraft maintenance services for any transient Air Force aircraft landing at that airport. The Air Force does not know when or how many aircraft will land at the airport, but it wants an agreement with the airport to refuel the planes. Therefore, the Air Force signs a binding commitment with the airport to service its aircraft if they land at that location.

The Air Force may want to secure a "letter contract" for a particular item for long range planning purposes. For example, the Air Force may require immediate contractor support to launch a rocket even through the contracting officer and firm have not signed a formal contract. The letter contract authorizes the contractor to start work on a project immediately, before it concludes contract negotiations with the contracting officer.

The Air Force also uses a "time and materials contract," that allows reimbursement to the firm for the cost of labor at a fixed hourly rate and reimburses the firm for the cost of any materials. For example, the Air Force may want to hire a consultant for a short period to work on a research project. The contracting officer will pay the consultant for his billed labor hours and the cost of any materials.

2.1.4 PROGRESS PAYMENTS

Firms can receive periodic payments, called progress payments, for their work instead of a lump sum payment. FPI contractors can receive a progress payment for incurred costs.[8] The contracting officer will allow a payment based on contractor submitted invoices and vouchers. The standard progress payment for an FPI contract is 80 percent of total costs incurred for large businesses and 90 percent for small businesses during the claimed period. The contracting officer deducts the amount of the

8. See FAR, Sec. 32.5.

progress payments from the total payment for the contractor when it receives the completed product or service. Normally, the contracting officer does not make progress payments to contracts with values of less than $1 million. The FAR requires the contracting officer to make progress payments if the contract involves a small business or the same contractor performs several contracts with a total value of over $1 million.[9] The FAR does not consider interest for these progress payments. FFP contract awardees can request progress payments, but they also must submit invoices and vouchers for their payments.

Contractors under a cost reimbursement contract also can receive progress payments. The contractor can get 100 percent reimbursement for costs plus a portion of the fee (f for CPFF contracts and f_{min} for CPIF contracts) as specified in the appropriate contract clause.

2.1.5 SMALL BUSINESS CONTRACT AWARDS

The contracting officer can openly compete a contract among all qualified bidders or award a contract based on the size and ownership of the bidding firm. Normally, the contracting officer awards a contract by using an invitation for bid (IFB) among all qualified bidders. This means any firm can offer a bid or proposal to win a contract award. However, the federal government has a contracting policy that helps small and disadvantaged businesses.[10]

Federal law requires that a contracting officer determine if a small and disadvantaged business can successfully complete the project.[11] The contracting officer, if he determines the project eligible for Small Business Administration (SBA) action, turns over the process of identifying bidders to the SBA. The SBA identifies potential bidders from a pool of qualified small and disadvantaged businesses. The SBA also can

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9. Ibid, Sec. 30.673.
10. See FAR, Sec 19.201.
11. See Department of the Air Force, United States Air Force Project Manager's Guide For Design and Construction, p. 3-25.

identify and select specific contracts for this restricted bidding from any federal agency.

If the SBA requires competition for the contract among a pool of qualified firms, the SBA refers to these projects as section "8(d)" (from the Small Business Act procurement regulations) awards.[12] These firms must meet the definition of a small socially or economically disadvantaged business. The FAR defines a small business as one that is not "dominant in the field of operation in which it is bidding on a government contract."[13] The business also must be "51 percent owned by one or more individuals who are both socially and economically disadvantaged, or a publicly owned business having at least 51 percent of its stock owned by one or more socially and economically disadvantaged individuals and has its management and daily business controlled by one or more such individuals."[14] Socially disadvantaged individuals include persons that have been subjected to racial or ethnic prejudice (e.g., Hispanic Americans). Economically disadvantaged individuals means individuals unable to compete in the free market due to limited access to capital or credit (e.g., woman-owned business). The firms must meet all of the following conditions for an 8(d) award:

a). The contracting officer believes he will receive at least two or more responsible bids from small and disadvantaged businesses.

b). The award is not above 110 percent of the government cost estimate.

c). The contracting officer believes that the bidders can provide the appropriate scientific or technical talent consistent with the project.

If the firms do not meet all the above requirements, the contracting officer can award the contracts by IFB.

The SBA also can award, without competition, a contract sole source or "8(a)" awards.

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12. Ibid, p. 4-1.
13. See FAR, Sec 19.001.
14. Ibid, Sec 19.001.

2.2 THE HISTORY OF MILITARY CONTRACTING POLICY

In the last few years, there has been much discussion concerning military contracting activities and policy. This section briefly examines the history of the military's contracting policy. Throughout the military's history, the government has made many changes to contracting procedures. Thus, history must be considered to understand how the Air Force developed and applies its present military construction contracting policy to satisfy its unique requirements.

How did modern contracting practices evolve to the FAR from earlier efforts? A system of invitation for bids (using FFP contracts) began in 1809 by direction of the Congress.[15] This process used a rigid system of formal advertising and lowest sealed bid awards in order for the government to benefit from open competition and to avoid the appearance of granting special consideration to any individual bidder. The system relied on a centralized government procurement agency. During the War of 1812 the centralized procurement system fell apart, as evidenced by long delays in supplying military units.[16] The inadequate logistical support during the war forced the Congress to allow individual federal agencies to administer their own procurements.[17] The authority of separate military services to purchase weapons, products, and services has remained in their hands since then.

Although the Congress allowed federal agencies to use the lowest sealed bid award and the FFP contract, the individual federal agencies did not always use this contract award method or contract type. The Army started to use performance incentive contracts earlier in this century. The performance incentive contracts were based on a firm's ability to

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15. See Air Force Institute of Technology 1987(a), Introduction to Acquisition Management, p. 6-4.
16. See Millett, A Military History of the United States, p. 120.
17. See Perret, A Country Made by War, p. 113.

reduce the scheduled product delivery times or provide better performance than the original contract technical specification. For example, in 1907 the US Army's first aircraft contract signed with the Wright brothers for their Wright Flyer aircraft, at $25,000 per plane, provided a performance incentive in terms of carrying load, endurance, and speed. Exceeding any one of the specifications would provide additional fees for the Wrights. Any 1 mph increase in speed from 40 mph up to a maximum of 44 mph increased payment by a 10 percent bonus. The contract specifications also imposed a 10 percent penalty for each 1 mph drop in speed from 40 mph to 36 mph. If the plane dropped in speed to a maximum less than 36 mph it was not accepted.[18] The Wrights' first aircraft achieved a maximum speed of 42 mph. The Army paid the Wrights $30,000 for the plane instead of $25,000.[19]

Some of the most significant changes in military contracting occurred after World War I. The Congress got involved with federal government procurement because of the image of excessive profiteering by munitions manufacturers during World War I. Between World War I and II, the Congress enacted approximately 170 procurement bills to control contractors doing business with the federal government.[20] The most important procurement act to affect the military was the Vinson-Trummel Act of 1934. This Act originally limited firms to a 10 percent profit rate on naval vessels and eventually was amended to include other items (e.g., a 12 percent rate for aircraft).[21] The Act required a contractor to return any profits above these rates via contract renegotiation. During World War II, the Congress revised and later dropped the profit rate limits.

The Congress only allowed FFP and CPFF contract types to be used after World War I, but most contracts were FFP. For example, the Army eliminated most CPFF contracts for military construction when the Quartermaster Corps transferred all construction work to the Army Corps of

18. See Anderton, History of the Air Force, p. 15.
19. Ibid, p. 16.
20. See Apagos, Government Industry and Defense Economics and Administration, p. 104.
21. See Nash and Cibinic, Federal Procurement, p. 127.

Engineers (COE) in 1941.[22] The Army could only use cost reimbursement contracts for expediency or when a project had extreme technical risk.

The federal government rarely used negotiated contracts (i.e., no first sealed bid process) prior to World War II because of the Appropriations Act of 1861, which required federal government agencies to use formal advertisements to obtain competitive bids for an award.[23] This resulted in the rare use of negotiated contracts. Some exceptions in this legislation included goods and services requiring immediate delivery and personal services contracts. The Congress changed the law affecting negotiated contracts in 1941 with the passage of the First War Powers Act of 1941.[24] The Act permitted contracting officers to use negotiated procurements on a wider scale (the military could use negotiated contracts in World War I by executive order only). The Armed Services Procurement Act of 1947 allowed the military, Coast Guard, and the National Advisory Committee for Aeronautics (forerunner of the National Aeronautics and Space Administration) to use negotiated procurements during peacetime for the first time.

The Armed Services Procurement Act of 1947 also created the Armed Services Procurement Regulation (ASPR). The ASPR required all contracting officers to follow the contracting policy within the regulation. The ASPR specified that government contracting officers should use formal advertising to attract bids for contract work. Contracting officers could use incentive contracts if they resulted in better performance (e.g., lower payments for the federal government) from the contractor. The ASPR was initially 125 pages.

Today the FAR has replaced the ASPR and its various supplements. By 1987 the FAR was 1,200 pages long, with daily page changes.[25] These changes reflect the growing concern and interest in federal government procurement. Individual federal agencies also provide unique procurement

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22. See Risch, The Quartermaster Corps: Organization, Supply, and Services, p. 271.
23. See Industrial College of the Armed Forces, Procurement, p. 19.
24. Ibid, p. 20.
25. See Fox, The Defense Management Challenge, p. 17.

guidance within their organizations in the form of FAR supplements. Contract policy has become increasingly complex and detailed since 1947.

2.3 AIR FORCE MILITARY CONSTRUCTION CONTRACT POLICY

This section provides a description of the Air Force military construction procurement process. This description traces the steps the contracting officer uses to get a project approved, funded, and awarded to a firm. This section first defines what constitutes a major construction project. Second, this section provides a comprehensive discussion of the size of the Air Force major construction program and how the Air Force awards a contract to a firm for a military construction project.

2.3.1 THE AIR FORCE MILITARY CONSTRUCTION PROGRAM

The Air Force classifies construction projects into four types: operations and maintenance (O&M), equipment installation, minor construction, and major construction. The following table defines the four classifications:

Construction Type	Criteria
Operations and Maintenance	Repairs an existing facility without adding a new capability to the facility.
Equipment Installation	Costs < \$200,000 and installs a piece of new equipment.
Minor Construction	Costs < \$200,000 and adds a new capability to a facility.
Major Construction	Costs > \$200,000 and adds a new capability to a facility or involves equipment installation.

The services request budget authority and control project funding differently for each construction type.

The Air Force includes O&M projects as part of normal real property maintenance activities. The Air Force does not identify specific O&M projects as separate line items in its annual budget. Instead, if the project is a repair of an existing facility it is included under an ongoing facility repair and maintenance contract with a private contractor. Individual Air Force bases request a total amount of funding for O&M projects, and after they receive funding they prioritize repair projects. These projects include minor repairs to facilities, grounds maintenance contracts, utilities repair, engineering support, road repair, and other similar work.

The Air Force includes specific equipment installation requirements as part of an equipment procurement request if the installation costs less than $200,000. This includes the initial siting and installation of any piece of new equipment as a part of the acquisition cost. If the equipment installation costs greater than $200,000, it is considered a major military construction project.

The Air Force manages the minor construction budget like the O&M budget. The Air Force consolidates all minor construction requirements into a single budget request.

The Air Force identifies and requests funds for individual major construction projects, and the Congress authorizes and appropriates funds for individual major military construction projects. After the Congress appropriates the funds, the Air Force can obligate those funds by awarding a contract for the project.

The military services request funds for major and minor military construction in the consolidated annual Military Construction Appropriations Bill. The request for major and minor military construction funding also includes the appropriate architectural and engineering support for these projects. The services request all other appropriations for O&M, equipment purchase, military personnel, and research & development under the annual Defense Appropriations Bill.

2.3.2 THE AIR FORCE MILITARY CONSTRUCTION BUDGET

The Congress appropriates military construction funds to active USAF, Air National Guard (ANG), and Air Force Reserve (AFRES) forces. The following list describes these appropriations (in $ million) for FY92:

	Active	ANG	AFRES	Total
Major Construction	$1235	$132	$21	$1388
Minor Construction	7	2	3	12
Architectural & Engineering	108	13	10	131
Total	$1350	$147	$34	$1531

2.3.3 THE CONTRACTING PROCESS

The Air Force must accomplish several actions before it can allow a firm to start construction on a facility project. It must identify its facility requirements, receive funding, and select a firm to construct the facility. These actions involve many organizations throughout the federal government.

An Air Force facility user begins the acquisition process by preparing a statement of need. This statement of need, via a Defense Department (DD) Form 1391, provides a description of the facility requirements, reason for the facility, and an initial cost estimate. The base civil engineering unit, under whose jurisdiction the proposed facility falls, prepares the DD Form 1391 with the organization that requests the facility. The DD Form 1391 also becomes an initial input for subsequent budget submissions to the Administration and the Congress.[26] This form provides an Air Force and DoD-wide standard approach for comparing worldwide facility requirements and enables the Air Force to rank projects by estimated cost.

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26. See Department of the Air Force 1989(i), United States Air Force Project Manager's Guide for Design and Construction, p. 2-7.

An important task for the civil engineering unit preparing the DD 1391 is to estimate the project cost. The Air Force uses these cost estimates to prepare budget requests. The civil engineering unit uses an Air Force cost model (the Construction Cost Management Analysis System (CCMAS)) to estimate the facility cost. The CCMAS provides an estimate based on proposed size, function, and location of the facility. The model calculates labor and material costs based on engineering specifications for the facility. These labor and materials costs provide the basis for the Air Force to predict construction costs, life cycle costs, and to conduct other cost analyses such as sensitivity analyses. The Air Force Engineering and Services Center developed and maintains the CCMAS.

The CCMAS provides cost estimates by decomposing the project into a work breakdown structure of engineering specifications. The CCMAS then defines the specific construction tasks a firm needs to accomplish to meet an engineering specification. The model uses data from an annual COE survey, conducted in the United States, to price these construction tasks and estimate the cost of the engineering specifications. This survey includes up to 25,000 construction tasks. The Air Force claims that the CCMAS can estimate construction costs within 7.5 percent of actual construction costs without engineering drawings.

The base civil engineering unit then sends the completed DD Form 1391, through the appropriate major command (MAJCOM)[27], to the Office of the Civil Engineer at Headquarters United States Air Force (HQ USAF/CE) for review. If HQ USAF/CE approves the project, the originator of the DD Form 1391 can initiate a funding request through the budget process. This request includes the actual construction costs, life cycle costs, and project administrative costs. This total life cycle cost provides a more comprehensive approach to comparing different designs and projects instead of just looking at one-time construction costs. Throughout the budget process the level of funding for the facility may change due to modifications in policies or budgets by the Administration or the

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27. The Air Force organizes its forces by function and geographic location into MAJCOMs. During this study period, the Air Force had 12 MAJCOMs. These MAJCOMs are directly subordinate to HQ USAF.

Congress, and the Air Force may have to alter the size of the proposed facility in response to these changes. The DD Form 1391 is amended to reflect the new changes.

After the project receives funding, the Air Force turns over management of the facility design and construction to the COE or Navy Facilities and Engineering Command (NAVFAC) depending on geographical location. The Air Force turns over project jurisdiction to the COE or NAVFAC by law, except for construction projects in the United Kingdom (the Air Force manages all military construction for the DoD in the United Kingdom).[28] However, the Air Force can ask the Army or Navy to allow it to contract and perform all construction management for the facility, but this occurs for only 20 percent of all contracts in the United States.[29] The MAJCOM provides a point of contact between the COE or NAVFAC and the Air Force base civil engineer.

The Army and Navy have divided the jurisdiction over military construction based on the predominant service in the geographic area. For example, the Navy has a larger presence in Hawaii than the Army, therefore NAVFAC controls all construction for the military services in Hawaii. The COE and NAVFAC charge a fee for their services (a 6 percent fee based on estimated cost) that the user must fund.

The MAJCOM provides a project book (written by the base civil engineering unit) for each facility initiative. This project book includes all the facility requirements and specifications, the DD 1391 estimated cost, and other information. The contracting officer uses this project book to develop facility specifications and requirements to contract out for the facility design and construction work. If the Air Force decides to change a specification (e.g., due to operational requirements), then the base civil engineering unit updates the project book and passes the revision to the MAJCOM for transfer to the appropriate contracting agency.

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28. See Department of the Air Force 1955(d), AFR 88-3 New Construction, p. 1.
29. Interview with Robert Boyer, Chief of Contract Policy for the Navy Facility and Engineering Command, HQ NAVFAC, Alexandria, VA on 18 Jul 1990.

The COE or NAVFAC can start their acquisition efforts when they get the project book. The contracting officer develops the overall contract strategy, with Air Force input from the base civil engineer, facility user, and others. The contracting officer then selects a government agency or a firm to start the design of the facility.

The contracting officer can select a private firm, government agency, or use an Air Force supplied design to complete the architectural and engineering plans. If the Air Force, Army, or Navy designs the facility it does not charge the facility user for the designs. The federal government normally contracts separately for the design and actual construction work.

The Air Force, Army, or Navy designs the facility if they have the expertise, interest, or time to complete the plans. Otherwise, the contracting officer awards a contract for the plans to private architectural and design firms. If the service contracts out the work, the firm must provide a written warranty against any engineering design flaws in its work. This is important, since the contractor who builds the facility by using these plans may encounter problems and later sue the federal government for additional modification costs for any mistakes in the plans. The architectural and engineering firm must either provide revised plans or funds to cover damages caused by their facility design.

The appropriate contracting officer normally contracts out for a design by an architectural and engineering firm by using a request for proposal (RFP). Each bidder provides its cost estimate and unique technical proposal. The contracting officer (with appropriate technical support from civil engineering officers, legal experts, etc.) must then evaluate each reply to the RFP and can conduct individual negotiations with each bidder. The bidders then provide a best and final offer with their revised bids and technical proposals after the contracting officer reviews its design with each firm. The contracting officer selects a firm based on these offers. Normally, the contracting officer awards an FFP contract for this effort.

After the start of the architectural and engineering design work, the contracting officer begins planning his contract strategy for the actual construction work.

For most construction projects, the tasks involve projects that have well-defined specifications. This results in the use of a first price sealed bid auction and FFP contracts in most cases. In the past, if the contract requires exotic materials, unique construction techniques, or other "non-standard" conditions the COE or NAVFAC has used certain cost reimbursement contract options. The use of cost reimbursement contracts valued at over $25,000 requires special justification, service secretarial level approval, and review by the Assistant Secretary of Defense for Production and Logistics. This is an additional requirement for cost reimbursement contracts levied by the DoD for military construction contracts only.

The contracting officer also must consider two other factors in the contract process: construction fund appropriations and the Small Business Act. The Air Force, Army, or Navy have two fiscal years to obligate military construction funds. If a contracting officer does not get a firm on contract to construct a facility before the funds expire, the funds are returned to the Treasury. The two year fund life allows the contracting officer to plan and execute a contract with more flexibility to make design changes and complete construction. The contracting officer also might have to use operations and maintenance funds. These funds have a one year life; this may affect the type of contract used since the contracting officer must get these funds on contract quickly before the funds expire. Several contracting officers have indicated that they used the lowest sealed bid method and FFP contract to award the contract because of the funding time constraint.

The contracting officer also has a requirement to award set aside contracts for woman- and minority-owned, small and disadvantaged businesses. The contracting officer must accept bids from only these businesses regardless of past performance (unless permanently debarred) or capability. The contracting officer then awards the contract between these businesses by holding a sealed bid competition. The Small Business

Administration can certify any of these businesses as "competent" and the contracting officer must accept their bids. The Small Business Administration acts as the final authority to decide whether the military construction contract is awarded to a small and disadvantaged firm. An increasing fraction of the total military construction contracts fall under these types of awards. The federal government awarded half the dollar value in all its construction contracts for FY91 to small businesses.[30] These restrictions can severely reduce the number of bidders competing for a contract. This can increase project costs due to limited competition.

The federal government awards FFP contracts for most construction contracts and it uses the first price sealed bid award method. The contracting officer has one major problem with this type of award determination: he cannot control for "quality" contractors. They do get a "fixed" cost equal to the low bid, but this assumes the contractor will not seek any contract modifications or defaults. Because of the low bid and firm desire to increase profit, the bidder can try to reduce costs by using inferior materials or lower skilled labor. The contracting officer can only exclude known low bid, low quality contract bidders if they have a debarment history, cannot post bond on their work, or fail to qualify under a pre-award survey where the contracting officer investigates bidder capability.[31]

During construction, the COE or NAVFAC assigns a team of civil engineers to monitor contractor performance. The team tests the firm's work to determine if it meets building construction codes. These civil engineers also formally evaluate the contractor's performance on resource management, management effectiveness, workmanship, schedule, and an overall project rating. The team can give the firm a rating of unsatisfactory, satisfactory, or excellent.

30. Interview with *DoD* Small *Business Administration* Administrator, 1 June 1992.
31. Interview with Paul Zendzejec, Project Engineer for the Army Corps of Engineers, Omaha District on 19 Jun 1990.

If the firm gets an unsatisfactory rating, the contracting officer can start permanent contract debarment actions against the firm. Contract debarment restricts the firm from participating on present or future government work. The contracting officer must prove a history of unsatisfactory performance before it debars a firm.

2.3.3.1 INFORMATION MANAGEMENT SYSTEMS

Throughout the construction acquisition process, Headquarters United States Air Force (HQ USAF) maintains a standardized computer database (the Program, Design, and Construction database (PDC)) to record contract and project data. The Air Force designed this computerized system in 1974 and initially called it the "1959 System." HQ USAF used it to provide monthly status reports of service-wide military construction projects to the Congress. Initially, the Air Force located all the computers and printers for the 1959 System in the Pentagon. The Air Force also conducted all MAJCOM updates at the Pentagon. Some MAJCOMs and separate operating agencies felt that they could use this system for internal management if the emphasis changed from a monthly HQ USAF report to a real time database. The Air Force subsequently addressed the MAJCOMs' concerns in 1981 with the introduction of remote terminals and printers at MAJCOMs and other organizations.

The Air Force eventually decided to provide a more decentralized processing system to provide more flexibility within the MAJCOMs for planning. The current PDC system uses Wang minicomputers at each civil engineering office throughout the Air Force. This allows the interactive use of project data from base level to MAJCOM through HQ USAF. The system hierarchy only allows access to records under an organization's jurisdiction. This means that base level PDC users can only access their projects, while HQ USAF has access to all Air Force project data. The base level Air Force civil engineer can use the PDC information to monitor the status of a project's design and construction. HQ USAF uses the PDC data to support budget requests and deal with Congressional inquiries.

The PDC system can track all programming, design, and construction information on all Air Force military construction projects. These projects include all major military construction (active, AFRES, and ANG), minor military construction, equipment installation, military family housing, commissary, non-appropriated funded, and operations and maintenance projects. These projects can be updated at the HQ USAF, MAJCOM, or base levels for a particular project. The system allows HQ USAF, MAJCOMs, and base level civil engineering officials to update cost, technical, or schedule information for a project. This allows decision makers at all levels to obtain current information almost instantaneously.

III. THE AIR FORCE MILITARY CONSTRUCTION PROGRAM

This chapter provides a description of Air Force military construction contract awards completed from 1980 to 1989. These contracts are analyzed on several dimensions. This evaluation first looks at the size of the contract based on the initial contract dollar award. Second, this chapter analyzes contract awards by geographic location of award. Third, the chapter examines contracts based on how the contracting officer awarded the contract. Fourth, this evaluation surveys what military construction project types the Air Force pursued during the period. Fifth, the study focuses on the number of bidders per contract based on contract award type.

The analysis between project types, contract award types, and other characteristics are made by using several statistical comparisons. Since this study uses the entire population of construction contracts, one can attribute the difference in contracts between characteristics as real. However, this study treats the data right as if it were a sample of all past and future construction contracts. Therefore, statistical tests can be made to determine if measures of interest differ. This is a more conservative approach to compare the data.

If we can analyze these contracts based on these distinctions, this helps us better understand the military construction program. This discussion also allows me to compare the current construction contracting situation to the incentive contract simulation results in Chapter V.

3.1 CONTRACT DOLLAR AMOUNTS

How large are the construction projects? Project size can be compared by square footage or number of rooms planned. Unfortunately, these characteristics may not consider other costly requirements, like security or environmental controls, that are not reflected in these measures. Also, the Air Force built some

projects as total "systems," not measured in square feet. This study uses dollars as a proxy for the construction effort; it assumes that the more complex a project, the higher the cost.

The average value of a construction contract (in FY90 constant dollars) is $5.3 million. The contract awards include competed contracts (IFB and 8(d)) and sole source awards (recall from Chapter II that IFB contracts were openly competed among all bidders and 8(d) awards competed among small, disadvantaged businesses). Contracting officers also award sole source contracts (8(a)) to small, disadvantaged businesses. The competed contracts averaged $5.5 million, while the sole source contracts have a mean value of $3.8 million.

The mean value of competitive contracts seems high relative to sole source bidder awards. The contract award type within the project type also differs in dollar amounts. For example, IFB research and development contract awards averaged about $14.3 million, while 8(d) research and development contracts had a mean value of $6.0 million. The overall research and development average contract value was $10.4 million. Since the contracting officer selected the 8(d) contracts for their technical ease, one would expect lower contract values.

The mean dollar value of contracts does differ among project types. The higher contract awards went to medical facilities ($20.1 million) and research and development projects ($10.4 million). These types of projects normally require specialized construction to support equipment, environmental, or stringent operating conditions.

Some interesting observations for the contract award type and average awards for project type are revealed by the data. Although the utilities and energy projects had a relative low overall average contract award, the contract low bids differed greatly between IFB or 8(d) awards. These projects have a higher openly competed IFB contract award ($6.3 million) versus the lower $1.9 million 8(d) contract award. Sole source awards were even lower at $1.6 million. Most of the contracts in this construction category deal with the utilities and energy projects.

Another comparison for these contracts involves the percentage of total dollar value based on contract award. See Table 3.1 for details of contract awards as percentages of the military construction program from 1980 to 1989.

The federal government awarded most of the contracts (93.1 percent) based on total dollar value, using some level of competition. In the past, the DoD has not contracted for its overall programs as competitively as military construction. In 1959, the DoD awarded 53.8 percent of total dollar contract values by competitive award (based on IFB and solicited by multiple sources).[1] According to Gansler, from 1962 to 1976, the DoD decreased competitive awards to about 40 percent of total dollar contract values.[2] McAfee and McMillan confirm these observations.[3]

3.2 CONTRACT AWARDS BY GEOGRAPHIC REGIONS

During the period, the Air Force awarded 1367 contracts and completed military construction projects in 45 of the 50 states. The Air Force built these projects on active, ANG and AFRES bases and installations. The five states that did not have any military construction projects contain no active Air Force bases or major installations. The state with the most contract awards was Texas (147) followed by California (145) and Florida (111). California has the highest average contract value ($13 million, in constant FY90 dollars) per construction project. California, Texas, and Florida have the largest number of active, ANG, and AFRES units and personnel assigned among all states during the time frame of this study. The least number of contracts awarded, by state, was in Wisconsin (1) and the smallest average contract value ($353.5 thousand) was in Connecticut.

For this study, states are grouped into nine census regions that the DoD's Directorate of Information uses to report contract awards to the Congress and public annually in their Prime Contract Awards by Region and State. These regions are:[4]

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[1]See Peck and Sherer, The Weapons Acquisition Process: An Economic Analysis, p. 324.

[2]See Gansler 1980(b), The Defense Industry, p. 76.

[3]See McAfee and McMillan 1985(b), Incentives in Government Contracting, p. 7.2.

1). New England (Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, and Connecticut).

2). Middle Atlantic (New York, Pennsylvania, New Jersey, Delaware, and Maryland).

3). South Atlantic (West Virginia, Virginia, District of Columbia, North Carolina, South Carolina, Georgia, and Florida)

4). East North Central (Wisconsin, Michigan, Illinois, Indiana, and Ohio)

5). East South Central (Kentucky, Tennessee, Mississippi, and Alabama)

6). West North Central (North Dakota, Minnesota, South Dakota, Nebraska, Iowa, Kansas, and Missouri)

7) West South Central (Oklahoma, Arkansas, Texas, and Louisiana)

8). Mountain (Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico)

9) Pacific (Washington, Oregon, California, Alaska, and Hawaii).

The region with the most contracts is the West South Central, followed by the South Atlantic and the Pacific regions. Very little construction took place in the New England, the Middle Atlantic, and the East North Central regions. These regions include 35 percent of the states and contain 17 percent of Air Force bases, but contained only 7.3 percent of the total contract awards.

See Table 3.2 for a regional breakdown of the percentage of construction contract dollars (in millions). The DoD spent the most contract funds, as a percent of the total defense budget, in the Pacific region in FY89.[5] The federal government awarded a high concentration of IFB contracts in the Pacific. Conversely, contracting officers awarded a relatively high proportion of 8(a) awards in the West South Central region.

[4]See Department of Defense 1991(b), Prime Contract Awards by Region and State FY 1990 1989 1988, p. 4

[5]Ibid, p. 5

TABLE 3.1

CONTRACT DOLLAR VALUES BY AWARD TYPE

CONTRACT AWARD TYPE	% TOTAL CONTRACT DOLLARS
IFB	44.4
8(d)	48.7
Sole Source	6.9
TOTAL	100.0

TABLE 3.2

CONTRACT DOLLAR VALUES BY REGION

CONTRACT AWARD

REGION DOLLARS	IFB	8(d)	Sole Source	% TOTAL CONTRACT
New England	2.4	1.6	0.1	4.1
Middle Atlantic	2.9	0.6	0.1	3.6
South Atlantic	2.9	9.7	1.2	13.8
East North Central	5.1	4.2	0.2	9.5
East South Central	0.7	3.2	1.0	4.9
West North Central	3.9	1.1	0.7	5.7
West South Central	4.3	11.3	1.0	16.6
Mountain	4.1	8.3	1.4	13.8
Pacific	18.1	8.7	1.2	28.0
Total	44.4	48.7	6.9	100.0

3.3 CONTRACT AWARD TYPE

Contracting officers awarded most contracts by IFB or 8(d) means. Table 3.3 provides a breakdown of contract awards. Most of these contracts were competed between at least two firms (89.2 percent of all awarded contracts). The government awarded few contracts sole source.

The DoD requires the Air Force to award construction contracts valued at less than $2 million to small, disadvantaged businesses.[6] The Air Force may award contracts with a value of more than $2 million to small, disadvantaged businesses. 56 percent of the Air Force's 8(d) contracts and 45 percent of IFB contracts have estimated costs of less than $2 million. These IFB awards did not fulfill all the requirements for an 8(d) or 8(a) award (see Chapter II for these requirements).

During FY91, small, disadvantaged business awards made up 56 percent of construction awards of the entire federal construction contracts awarded.[7] The DoD accounts for the largest single agency award of SBA contracts. This is not surprising since the DoD is the largest agency in the federal government.

The DoD has an established objective of awarding at least 5 percent of all DoD contract dollars as 8(a) or 8(d) awards. The DoD and SBA have traditionally set the goal for construction much higher than the 5 percent objective. This emphasis comes from the large number of small building contractors and the relatively easy conversion from private to military construction. Similarly, construction (excluding home building) generated significant numbers of new jobs in small, disadvantaged businesses (e.g., 208,000 jobs from June 1987 to 1988) during most of the study's period.[8] In The State of Small Business, A Report of the President, the SBA estimated that the construction industry has the second highest number of firms with one to four employees.

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[6]See Small Business Administration 1988(a), The State of Small Business: A Report to the President 1988, p. 175

[7]Interview with Director of Small and Disadvantaged Business Utilization, Office of the Secretary of Defense, 4 May 1991.

[8]See Small Business Administration 1989(b), The State of Small Business: A Report to the President 1989, p. 18.

3.4 PROJECT TYPES

This section describes the different project types built by the Air Force. Not all construction projects have the same requirements or specifications. Unlike construction during World War II, where the services standardized building designs and specifications worldwide (e.g., quonset huts), the Air Force does not follow this policy (except for some operational facilities). Instead, the Air Force tries to design facilities that are architecturally compatible within the local area. These distinctions may affect different contract bid behavior and eventual Air Force contract payment. Some contracts may only need general contractors, while others may require specialists. For example, if the Air Force builds a test laboratory in Montana, construction firms in Montana may not have the expertise or physical capital to complete the contract.

See Table 3-4 for a summary of the contract awards by project types. The most frequent project type involves operational facilities and the least common project type was medical facilities.

The project type classification includes facilities that range from hangers to electrical power plants. The operational facilities project type includes hangers, ICBM missile facilities, and air traffic control towers. The maintenance and logistics repair project type involves facilities related to weapon or support systems upkeep. The Air Force classifies laboratories and test facilities as research and development facilities. The warehouse and storage facilities project type includes buildings ranging in size from tool sheds to multi-story supply warehouses. The Air Force classifies any facility providing health care as a medical facility. These facilities include hospitals and medical clinics. The administrative and computer facilities include office buildings and dedicated facilities for computer operations. Living and personnel support classification is made up of buildings like dormitories and mess halls. Civil engineers also classify electrical power plants, steam generating plants, and energy saving facility upgrades as a part of the utilities and energy project type.

TABLE 3.3

CONTRACT AWARD DISTRIBUTION

CONTRACT AWARD TYPE	NUMBER	% TOTAL
IFB (competed)	339	24.8
8(d)(competed)	881	64.4
Sole Source	147	10.8
TOTAL	1367	100.0
Sole Source		
IFB (one bidder)	2	1.3
8(d) (one bidder)	22	14.9
8(a)	123	83.8
TOTAL	147	100.0

TABLE 3.4

PROJECT TYPE DISTRIBUTION

CONTRACT AWARD

PROJECT TYPE	IFB	8(d)	8(a)	Total	(%)
100	88	235	31	354	(25.9)
200	56	226	34	316	(23.1)
300	34	29	5	68	(4.9)
400	27	38	12	77	(5.7)
500	11	12	4	27	(1.9)
600	11	55	15	81	(5.9)
700	51	129	45	225	(16.5)
800	61	157	1	219	(16.1)
	339	881	147	1367	(100.0)

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

3.5 BIDDERS

How many bidders bid on these contracts? Competitive contracts have a mean of 7.6 bidders per project (the median value is 7). IFB contract awards had a mean of 8.6 bidders per contract (median 7.5), while 8(d) awards averaged 7.2 (median 7).

See Table 3-5 for the number of bidders by project type. The maintenance and logistics repair facilities projects had the highest number of mean bidders, 9.2, for IFB awards. 8(d) awards had only 6.7 bidders. This project type is similar to commercial facilities, and this may explain the higher number of bidders among IFB awards.

I might expect that the higher number of bids creates stronger levels of competition among bidders and thus, firms lower their bids. As a firm sees more bidders for an award, they need to lower their bid amounts to increase their probability of winning the contract award. Under first price sealed bid awards, the contracting officer does not reveal the number of bidders to anyone until the public bid openings. However, some contracting officers have mentioned that in their opinion, many construction firms know who will bid on particular contracts through informal communications within the industry. These firms should reduce their bids to reflect the minimum amount to compensate them for their expected costs and profit to win the contract award. Conversely, fewer bidders should increase bid amounts due to the lack of competition.

3.6 COMPARISONS BETWEEN ESTIMATED COST AND BID AMOUNTS

An interesting comparison for military construction contracting is the examination of how current bidders bid compared to the estimated Air Force cost estimate for construction projects. This represents how competitive bidders might bid compared to the project's size (based on dollar cost estimates). If the firms want to win the award, one would expect that firms would bid closer to the Air Force cost estimate (assuming this cost estimate is accurate). Conversely, if the

firms know they face little competition, they might not lower their bids.

Accordingly, the average contract bids were approximately 8.13 percent (n = 1367) below the Air Force cost estimate for all contracts. The Air Force "saved" money in its contracting practices. This estimate is used as a "measuring" stick to compare different contract strategies. The purpose of this analysis is to use the estimate as a base to compare relative bidding between contracts. Since the Air Force uses the same cost estimation system for all project types, this allows the comparison of many different contract characteristics.

See Table 3.6 for these contract award values. IFB awards had bids about 11.4 percent (n = 332) below the estimate. Conversely, 8(d) contract bidders made bids with a mean of 9.5 percent (n = 881) below the estimate. Using a z test, we test the hypothesis that the IFB awards are significantly lower than 8(d) awards. The test results indicate that their difference is significant at the 1 percent significance level. This means the cost of competition between fully open and restricted competition is about 1.9 percent. This seems fairly small, but the difference could have been greater if IFB bidders had the opportunity to bid on 8(d) awards.

Sole source bidder awards show a completely different picture. The average value of 8(a) contract awards was 7.4 percent (n = 147) <u>above</u> the cost estimate. Do these contract awards really represent higher amounts of bids than IFB or 8(d) awards? Assuming that the contract award percentage differences are normally distributed, a standard t test can be used to test if the sole source awards differed. The difference is greater than 0 at the 1 percent significance level.

A comparison of mean values for 8(a) contracts to means of IFB awards, reveals a large difference of 18.8 percent. This cost of competition is the amount the Air Force sacrifices to award 8(a) contracts, perhaps it should consider reducing their use due to the high cost. However, the federal government might view the awarding of these 8(a) awards as a means to help a particular small and disadvantaged business. For example, the federal government may want to help a minority-owned firm to survive successfully in the construction industry.

TABLE 3.5

NUMBER OF BIDDERS BY PROJECT TYPE

	PROJECT TYPE							
	100	200	300	400	500	600	700	800
AWARD TYPE								
IFB	8.4	9.2	7.6	8.0	9.3	9.0	8.6	9.3
8(d)	7.2	6.7	6.8	7.6	7.5	8.4	7.7	7.0

TABLE 3.6

PERCENT DIFFERENCE BETWEEN LOW BID & COST ESTIMATE BY PROJECT TYPE

	PROJECT TYPE							
	100	200	300	400	500	600	700	800
COMPETITIVE								
IFB	-7.7	-11.6	-10.1	-9.1	-11.3	-7.7	-12.2	-3.1
8(d)	-9.9	-4.4	-10.1	-14.3	-7.3	-13.2	-0.7	-2.3
TOTAL	-9.1	-5.8	-10.1	-12.1	-9.2	-12.1	-8.2	-2.5
SOLE SOURCE								
IFB	-	-	-8.6	-	-	-	-	-31.0
8(d)	-	1.7	4.3	-0.5	-	7.3	-5.8	-4.3
8(a)	3.9	1.1	1.1	-1.4	-	5.5	3.4	27.7

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

Differences also occur in project types. See Table 3.7 for a description of differences by project type. The warehouse and storage and the administrative and computer facilities project types have the lowest difference in awards. These project types are most like their civilian counterparts in terms of construction specifications and requirements. The highest awards involve the utilities and energy projects.

A one way ANOVA test is used to explore whether the mean differences are the same for all project types by contract award. The test results indicate that the mean differences, by project types and contract award, are not the same at the 1 percent significance level.

There were real differences for certain individual project types. For example, the operational, the maintenance and logistic repair, and the utilities and energy project types had relatively wide differences between IFB and 8(d) contract awards. IFB contract awards have more underbidding for the maintenance and logistics repair project types. 8(d) contract awards have lower bids than IFB contracts for the operational project type. The utilities and energy projects have smaller differences between the lowest bid and the estimated costs than other projects. For other project types the differences by contract type are not statistically significant.

Generally, IFB contract awards have lower bids, compared to their cost estimates, than 8(d) and 8(a) awards by geographic region. See Table 3.8 for a table of differences based on region. The New England region had the lowest difference. The greatest difference between the level of lowest bids and the cost estimates comes from the Mountain region. Here, the Air Force built new space support facilities in Colorado and Peacekeeper ICBM silos in Wyoming.

3.7 CONTRACT BID VARIABILITY

The data also allows an analysis of contract bid variability within individual project. Contracts with much competition between bidders may indicate that firms have similar project cost estimates and, therefore, little bid variability between

TABLE 3.7

PERCENT DIFFERENCE BETWEEN LOW BID & COST ESTIMATE BY PROJECT TYPE

PROJECT TYPE

	100	200	300	400	500	600	700	800
COMPETITIVE								
IFB	-7.7	-11.6	-10.1	-9.1	-11.3	-7.7	-12.2	-3.1
8(d)	-9.9	-4.4	-10.1	-14.3	-7.3	-13.2	-0.7	-2.3
TOTAL	-9.1	-5.8	-10.1	-12.1	-9.2	-12.1	-8.2	-2.5
SOLE SOURCE								
IFB	-	-	-8.6	-	-	-	-	-31.0
8(d)	-	1.7	4.3	-0.5	-	7.3	-5.8	-4.3
8(a)	3.9	1.1	1.1	-1.4	-	5.5	3.4	27.7

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

TABLE 3.8

PERCENT DIFFERENCE IN LOWEST BID & COST ESTIMATE

REGION	IFB	COMPETED 8(d)	TOTAL	SOLE SOURCE
New England	-4.2	-10.4	-7.4	5.3
Middle Atlantic	-17.3	-12.0	-13.4	0
South Atlantic	-9.8	-10.4	-10.3	-1.0
East North Central	-4.9	-10.8	-8.9	-
East South Central	-17.1	-9.1	-10.5	8.6
West North Central	-8.5	-2.4	-8.5	0
West South Central	-14.0	-10.3	-10.8	-6.8
Mountain	-16.1	-13.6	-14.2	0
Pacific	-13.0	-1.7	-9.4	4.2

bidders. It also could indicate collusion in bidding between firms if the variability between bids is extremely narrow, or that the work is relatively well defined among firms. Conversely, a large relative range of bids means that bidders may have widely differing opinions about the amount of resources required to complete the project.

The variability between bidders can be measured by using the coefficient of variation. See Table 3.9 for a description of these values by project type. Kohler defines the coefficient of variation as a measure of relative dispersion without units.[9] This value can be used to compare the relative dispersion of at least two different distributions that are expressed in different units. The coefficient of variation value in this study is computed by dividing the standard deviation of the bid amounts by the mean of the bid amounts. This measure shows the amount of variance in bids between bidders in a contract award competition.

The coefficient of variation for contract types shows bid amounts differ between IFB and 8(d) competitive awards. The coefficient of variation between IFB and 8(d) contract awards did not differ greatly (7.6 percent between the lowest to highest contract bids for IFB awards and 6.6 percent for 8(d) awards). A more interesting comparison deals with the different project types. In the utilities and energy projects, the coefficient of variation shows the highest overall variance of 13.5 percent difference. The lowest variability was in warehouse and storage facilities at 5.85 percent under IFB contract awards. The highest variability was in the 8(d) medical facilities projects, 14.7 percent.

The coefficient of variation also might suggest the level of technical risk faced by the bidders. A relatively large coefficient of variation may represent bidders who have widely divergent cost estimates, hence bids, on a project. These opinions result in some firms purposely increasing their bids relative to others. These bidders may have increased their bids to ensure they do not underbid the work required for the project. Since the bidders may not know what the exact state of the world will be, in terms of events affecting construction (i.e., labor strikes, weather, or materials price increases), these bidders may face the prospect of building a technically risky project with little prospect of further reimbursement.

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[9]See Kohler, Statistics for Business and Economics, p. 115.

TABLE 3.9

COEFFICIENT OF VARIATION

PROJECT TYPE

	100	200	300	400	500	600	700	800
COMPETITIVE								
IFB	9.46	8.23	8.11	6.22	5.85	9.09	7.73	13.41
8(d)	8.91	8.19	9.09	13.15	14.73	8.56	8.37	13.48
MEAN VALUE	9.05	8.21	8.55	10.27	10.48	8.65	8.19	13.46

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

Within project types, the IFB and 8(d) awards differ greatly. The warehouse and storage and medical facilities projects provide good examples. These awards suggest greater uncertainty toward construction with regard to high technology or complex medical requirements on 8(d) bidders. Conversely, one sees a different situation with the warehouse and storage projects. These projects include facilities for storing supplies or equipment. One might, at first glance, believe these projects entail fewer technical requirements. However, many of these contracts include specifications for environmental and security systems unique to the military. This includes such requirements for nuclear weapons storage for air launched cruise missiles or hazardous waste storage facilities.

A Defense Systems Management College (DSMC) contract management instructor mentioned that the DSMC recommends that acquisition project managers and contracting officers use FFP contracts if the bid range varied between 0 and 5 percent from the mean bid. Additionally, the contracting officer should use incentive contracts if FFP contract bids range between 5 and 15 percent. If any contracts that have bids that vary greater than 15 percent, the contracting officer should use a cost reimbursement contract. I can use the coefficient of variation to calculate the percentage differences between the high/low bids and the mean. The coefficient of variation acts as an indicator of relative dispersion instead of using a percentage difference between the high and low bid values that might overstate the effect of extreme outliers for these contracts.

Notice in Table 3.9 many FFP contracts have bid differences that fit this level of incentive contract use according to the DSMC guidelines. Notice that the utilities and energy projects seem well above the minimum suggested level for incentive contract use.

The utilities and energy projects had a much higher level of variability than other project types. Many of these projects deal with the DoD Energy Conservation Investment Program (ECIP). The ECIP is a military construction program to retrofit existing facilities and introduce new construction that reduces related annual costs.[10] The Air Force evaluates ECIP projects based on the life cycle cost savings of energy consumption. If the project saves money for

[10]See Office of the Assistant Secretary of Defense, Defense Energy Program Policy Memorandum 85-2, p. 1.

the Air Force (considering life cycle costs and energy savings), it normally approves the project for construction.

The DoD had particular problems with energy monitoring and control systems (EMCS) for the ECIP.[11] Civil engineers from HQ USAF indicated that these particular projects had the most technical problems to complete than other project types. These EMCS projects attempt to provide optimal levels of electricity, heating, cooling, lighting, and other utilities for buildings on a base. A centralized control system on base directs the EMCS. Many of these projects require new technology and designs never seen in previous military construction projects. For example, many EMCS projects require central control units, software, field located microprocessor-based interface devices, data communications equipment, sensors, and control systems. For these projects, the contracting officers used FFP contracts. An official for the Air Force Engineering and Services Center suggested that many bidders did not adequately consider the technical uncertainties of the EMCS requirements. Several firms have litigated their contracts because they underbid the contract and blame the Air Force for not warning them of these specifications.

These issues may have caused some bidders to bid substantially higher than their expected costs. Conversely, uninformed bidders may have bid low just to win the bid or may not have been aware of the EMCS requirements. This situation created so many problems that the DoD Inspector General (report No. 85-004) recommended that contracting officers should only award components of the project as separate projects for 8(a) or 8(d) firms, not the entire contract.[12] Likewise, the IFB awarded projects needed more detailed identification of technically risky requirements.

3.8 NUMBER OF BIDS AND BIDDER BEHAVIOR

As the number of bidders increases, the difference between the lowest bid

[11] ibid. p.5.

[12] ibid. p.5.

and the estimated cost narrowed between contracts. This illustrates the idea that increased competition among potential firms might reveal true costs in terms of bids. Table 3.10 provides information from the bid data that supports this observation. The IFB awards have lower bids than 8(d) awards for contracts with bids greater than ten. The 8(d) awards have lower relative bids than IFB awards if the number of bidders is lower than ten. These results may affect the results of the simulated incentive contracts. Since the firms may have already reduced their bids greatly, compared to estimated costs, the incentive contract use may show lower savings rates since competition has reduced these bids.

TABLE 3.10

PERCENT DIFFERENCE BETWEEN LOW BID & COST ESTIMATE BY NUMBER OF BIDDERS

	Bidders ≤ 5
IFB	-4.5
8(d)	-5.6
	5 < Bidders ≤ 10
IFB	-12.1
8(d)	-12.2
	10 < Bidders ≤ 15
IFB	-15.5
8(d)	-9.7
	15 < Bidders ≤ 20
IFB	-19.9
8(d)	-15.9
	Bidders > 20
IFB	-23.1
8(d)	-16.1

IV. THE MCAFEE AND MCMILLAN MODEL

In this section, I describe the model for the optimal incentive contract based on R. Preston McAfee and John McMillan's research. I first explain the goals of the firm and government within the contract framework in which they operate. This helps distinguish the motivations of the firm toward bidding on a contract. Second, I present the McAfee and McMillan incentive contract model. Third, using the government's estimated payment function and the firm's estimated profit function, I calculate a formula to find the optimal share rate (α) that the government can use for this incentive contract. The model allows for moral hazard, risk sharing, and bid competition effects that influence bidder behavior. Fourth, I consider the results of the model for the firm and government. Fifth, I describe how to apply the McAfee and McMillan model to study the Air Force's military construction program.

4.1 THE FIRM AND GOVERNMENT

McAfee and McMillan develop an optimal contract based on an incentive contract. This contract type lowers the government's expected payments, taking into account bidder behavior. Specifically, the McAfee and McMillan contract minimizes expected payments by optimally balancing increased bid competition and risk sharing with lowered gains from moral hazard effects (cost reduction).

The model assumes n ($n > 1$) identical firms that maximize their expected utility $EU(\pi)$. Bidder utility depends on its profits (π) from a project. Each firm i, where $i = 1, \ldots, n$, realizes a total ex post cost, C_i. Profits are the difference between the government's payment (τ) and C_i, thus $\pi = \tau - C_i$. The firms share a common concave utility function, U. They must ensure $EU(\pi) \geq 0$ when they

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[1]See McAfee and McMillan 1985(a), Incentives in Government Contracting, p. 4 10.

bid.

The government's objective is to minimize $E(\tau)$. The government's specification for the award includes a calculated optimal value for α based on the number of bidders, range of expected costs, and an assumption about the severity of moral hazard. The government then selects the bidder based on the lowest bid and uses the optimal α to calculate payments to the firm. The firm then produces the good or provides the service. The government's payment depends on the firm's audited costs.

The McAfee and McMillan contract scenario differs from the actual process of awarding incentive contracts by the federal government, and I examine these differences in more detail in Chapter VI. Although this contract process differs somewhat from the McAfee and McMillan model, the government can still use their model. For example, the government could estimate an optimal α even if it does not know the exact number of bidders on the contract ex ante. It can estimate how many bidders will bid by the number of inquiries about the contract specifications or requests for contract bid instructions or by examining government cost estimates or historical data from similar projects. This allows the government to estimate an optimal share rate instead of subjectively selecting an α.

4.2 BIDDER COST

The ith firm incurs C_i, where:

$$C_i = c^*_i + \omega - \varepsilon_i, \tag{5}$$

and

C_i = Total actual project costs for the ith bidder.
c^*_i = Expected cost of the ith bidder, before cost reduction.
ω = Unpredictable costs.
ε_i = Cost reduction efforts by the firm.

The value c^*_i represents an estimated project cost made by the firm ex ante

is strictly non-zero for all c^*_i in $[c_l, c_h)$. The value c_h can take a value of positive infinity.

The variable ω is a stochastic disturbance and has a cumulative distribution function $F(\omega)$. The value of ω depends on unanticipated events that result in unexpected costs to the firm (e.g., labor disputes, weather). The firm cannot predict these costs or alter its bid after contract award based on ω. The government also does not observe ω, so the government cannot directly contract on ω with a bidder. All bidders face the same $F(\omega)$ distribution. It is assumed, without loss of generality, that this random variable has an expected value equal to zero, or $E(\omega) = 0$.

The value ε_i represents cost reduction efforts made by the firm. In an FFP contract, the contractor maximizes this effort since each dollar saved in cost reduction becomes additional profit for the firm. On the other hand, the firm will expend less effort for cost reduction under a cost reimbursement contract. Economists call this the "moral hazard" effect.

The firm incurs $h(\varepsilon_i)$, which represents the cost of effort to the firm to reduce project costs. The model assumes that $h'(\varepsilon_i) > 0$ and $h''(\varepsilon_i) > 0$; thus there are diminishing returns to effort. Although McAfee and McMillan assume $h(\varepsilon_i)$ is *not directly chargeable to the project*, the bidders might incorporate a value for $h(\varepsilon_i)$ into b_i. For example, the firm could scrap obsolete equipment, but this could reduce potential business in the future. The firm could calculate a scrap value of the equipment in its expected cost that affects b_i. Also, a bidder could put more managerial effort into reducing "waste," but this may entail a reduction in his leisure (not chargeable to the government).

The government (assumed risk neutral) considers these factors in designing a contract that minimizes $E(\pi)$. The bidders make bids based on their beliefs concerning c^*_i, ω, and ε_i.

4.3 INCENTIVE CONTRACTS

McAfee and McMillan use a linear incentive contract model that is the same

as an FPI contract under the current FAR. This contract takes the form:

$$\tau = \alpha C_i + \beta b_i + f. \tag{6}$$

Where τ = Bidder's total payment from the government

α = Cost share rate

β = Bid share rate

f = Ex ante agreed on fee

This contract form can represent many types of contracts. If $\alpha = 0$ and $\beta = 1$, then the contract appears as an FFP contract. The bidder, in contrast to the incentive contract, must consider paying for all unpredictable costs from its bid. If $0 < \alpha < 1$ and $\beta = 1 - \alpha$, then the contract is an incentive contract. The bidder pays a portion of any cost overrun to the government or has his payment reduced by this amount. The bidder needs to consider only a share of any unknown contingency; the government will reimburse a portion of the overrun. If $\alpha = 1$ and $\beta = 0$, then the contract is a cost reimbursement contract. If $\alpha = 1$, then the firm does not link the bid to its expected costs. The firm gets reimbursed for all allowable contract costs without a penalty.

The government may provide different values for α, β, and f in order to reduce contract payments. It will be shown that the key to reducing the government's τ is the α value.

For the purpose of designing the optimal contract, the values of f and β may be dispensed with. In a competitive situation, any increase in f should result in a decrease in the firm's bid by f/β. Therefore, f is not considered in the model. The expected τ is invariant to any changes in fee.[1] The model does consider β. The model can reproduce any (α, β) pair by another pair, $(\alpha, (1 - \alpha))$. In this model I substitute $(1 - \alpha)$ for β.

Dropping the value f and substituting $\beta = (1 - \alpha)$ in (6), the incentive contract becomes:

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[1]See McAfee and McMillan 1985(a), Incentives in Government Contracting, p. 4.10

$$\tau = b_i + \alpha(C_i - b_i),$$

$$= (1 - \alpha)b_i + \alpha C_i. \tag{7}$$

Equation (7) shows that a bidder's payment should equal his bid if he incurs no cost overrun or underrun ($C_i = b_i$). Overruns occur when $C_i - b_i > 0$, while underruns occur when $C_i - b_i < 0$. He also must pay for any overrun or underrun by an amount $(1 - \alpha)(C_i - b_i)$.

Note that this incentive contract acts as a partial insurance policy for the bidder. Unlike an FFP contract, the winning firm doesn't have to pay for the entire overrun; the government pays a portion of the cost.

4.3.1 BIDDER PROFITS UNDER INCENTIVE CONTRACTS

In order to understand how a bidder behaves, the government needs to evaluate a bidder's profit. Under an incentive contract, the bidder selects a level of ϵ to maximize $EU(\pi)$. The profit function is:

$$\pi_i = \alpha C_i + (1 - \alpha)b_i - C_i - h(\epsilon_i), \tag{8}$$

$$= \alpha(c^*_i + \omega - \epsilon_i) + (1 - \alpha)b_i - (c^*_i + \omega - \epsilon_i) - h(\epsilon_i), \tag{9}$$

$$= (1 - \alpha)(b_i - c^*_i - \omega + \epsilon_i) - h(\epsilon_i), \tag{10}$$

$$= (1 - \alpha)(b_i - c^*_i - \omega) + [(1 - \alpha)\epsilon_i - h(\epsilon_i)]. \tag{11}$$

The bidder maximizes $EU(\pi_i)$, where the expectation is taken over ω. The bidder will select a level of ε^o such that $\frac{dEU(\pi_i)}{d\varepsilon_i} = 0$. Taking the first order condition:

$$0 = EU'(\pi_i)((1 - \alpha) - h'(\varepsilon^o{}_i)). \qquad (12)$$

Rearranging, we obtain

$$\varepsilon^o{}_i = h'^{-1}(1 - \alpha). \qquad (13)$$

The value of $\varepsilon^o{}_i$ depends inversely on α. If the government makes the bidder responsible for a larger portion of the overrun, the firm will have an incentive to devote more effort to increase ε_i.

The bidder's new π function becomes:

$$\pi_i = (1 - \alpha)(b_i - c^*{}_i - \omega) + (1 - \alpha)(h'^{-1}(1 - \alpha)) - h(h'^{-1}(1 - \alpha)). \qquad (14)$$

4.4 BIDDING BEHAVIOR

One can characterize bidder strategy based on equation (14). Suppose the bidders base their bids on their costs according to a function $B(c^*{}_i)$; that is, the bidders set $b_i = B(c^*{}_i)$. Thus, I assume, as does McAfee and McMillan, that all firms bid identically as a function of their cost (this will be explored in more detail later).

The probability of the ith firm's bid, b_i, winning the contract (i.e., having the lowest bid) depends on the distribution of bids and the cost function. Therefore, the bidder's winning bid depends on the distribution of $B(c^*{}_i)$ and $G(c^*{}_i)$. Given a bid, b_i, the appropriate $c^*{}_i$ may be estimated by inverting $B(c^*{}_i)$, or $c^*{}_i = B^{-1}(b_i)$.

The probability of a rival firm making a bid lower than b_i depends on the distribution of costs, $G(B^{-1}(b_i))$. Therefore, the probability of another bidder making a higher bid is $1 - G(B^{-1}(b_i))$. Since we have n bidders, the probability of the firm making the lowest bid among all bidders is $[1 - G(B^{-1}(b_i))]^{n-1}$. Then a bidder's ex ante utility for a given bid, b_i, is:

$$EU(\pi_i) = [EU(\pi_i)]\left([1 - G(B^{-1}(b_i))]^{n-1}\right), \tag{15}$$

$$= [EU((1-\alpha)(b_i - c^*_i - \omega) + (1-\alpha)(h'^{-1}(1-\alpha)) - h(h'^{-1}(1-\alpha))][1 - G(B^{-1}(b_i))]^{n-1}. \tag{16}$$

The bidder will select a b_i that maximizes $EU(\pi_i)$; that is, he selects a bid that solves $\frac{dEU(\pi_i)}{db_i} = 0$ for equation (16). The first order condition is:

$$(1 - \alpha)\frac{EU'(B(c^*_i))}{EU} = \frac{(n - 1)g(c^*_i)}{1 - G(c^*_i)}. \tag{17}$$

Equation (17) determines the optimal bid function $B(c^*_i)$. Notice, if $\alpha = 1$ the bidder has no motivation to reduce costs, because profits or bids do not depend on c^*_i (see equation (14)), but some other factor. The government cannot tell which bidder has the lowest expected cost by their bid and the chance of the government selecting the lowest expected cost bidder is then $\frac{1}{n}$. Thus, the cost reimbursement contract cannot be considered optimal.

If $\alpha < 1$, the bidders will consider c^*_i ($B'(c^*_i) > 0$) for their bids. The bidder also considers its bid, ω, and its cost reduction efforts for its profit if $\alpha > 1$.

4.5 THE OPTIMAL INCENTIVE CONTRACT

If the government selects the lowest bidder with the expected cost, c^*_i, it should expect to pay:

$$E(\tau(c^{*})) = E((1 - \alpha)(B(c^{*})) + \alpha C_i). \tag{18}$$

Expected payment $E(\tau(c^{*}))$ may be reformulated (see Appendix 4.1 for proof) to:

$$E(\tau(c^{*})) = E\pi_i + c^{*} + [h(\varepsilon^{o}_{i}) - \varepsilon^{o}_{i}]. \tag{19}$$

In order to solve for the optimal bidding strategy, McAfee and McMillan assume that the bidders have constant absolute risk aversion:

$$U(x) = \frac{1 - e^{-\lambda x}}{\lambda}. \tag{20}$$

The value λ (where $\lambda \geq 0$) is a measure of risk aversion, and ranges from 0 to 1.

McAfee and McMillan evaluate (20) in terms of $EU(\pi(c^{*}))$. The firm's expected profit function is (see Appendix 4.2) calculated from (20):

$$E(\pi_i(c^{*}_{i})) = -\frac{1}{\lambda}\Big([\ln(n-1) - (n-1)\ln(1-G(c^{*}_{i})) - \ln\Big(\int_{-\infty}^{+\infty} e^{-\lambda(1-\alpha)(w)} f(w)\, dw\Big) - \ln\Big(\int_{c^{*}_{i}}^{c_h} e^{-\lambda(1-\alpha)(c-c^{*}_{i})} (n-1)[1 - G(c)]^{n-2}\, g(c)dc\Big)\Big). \tag{21}$$

Thus, rewriting equation (19), using (21), results in:

$$E(\tau(c^{*}_{i})) = -\frac{1}{\lambda}\Big([\ln(n-1) - (n-1)\ln(1-G(c^{*}_{i})) - \ln\Big(\int_{-\infty}^{+\infty} e^{-\lambda(1-\alpha)(w)} f(w)\, dw\Big) - \ln\Big(\int_{c^{*}_{i}}^{c_h} e^{-\lambda(1-\alpha)(c-c^{*}_{i})}$$

$$(n-1)[1 - G(c)]^{n-2}\ g(c)dc\Big) + c^{*}_{i} + [h(\varepsilon_i) - \varepsilon_i]. \tag{22}$$

The government solves for the optimal α by taking the first order condition ($\frac{dE(\pi(c^{*}_{i}))}{d\alpha}$) of equation (22):

$$0 = \frac{\alpha}{h''(h'^{-1}(1-\alpha))} - \frac{\int_{-\infty}^{+\infty} \omega e^{\lambda(1-\alpha)\omega} f(\omega)d\omega}{\int_{-\infty}^{+\infty} e^{\lambda(1-\alpha)\omega} f(\omega)d\omega} - n\int_{c_1}^{c_h} \frac{\int_{c^{*}_{i}}^{c_h} e^{-\lambda(1-\alpha)(c-c^{*}_{i})}(c-c^{*}_{i})[1-G(c)]^{n-2} g(c)dc}{\int_{c^{*}_{i}}^{c_h} e^{-\lambda(1-\alpha)(c-c^{*}_{i})} g(c)dc}$$

$$[1-G(c^{*}_{i})]^{n-1} g(c^{*}_{i})dc^{*}_{i}. \tag{23}$$

The calculation of the optimal α depends on three effects identified in (23). The three individual terms of equation (23) include:

Moral hazard: $\frac{\alpha}{h''(h'^{-1}(1-\alpha))}$. (24)

Risk sharing: $\frac{\int_{-\infty}^{+\infty} \omega e^{\lambda(1-\alpha)\omega} f(\omega)d\omega}{\int_{-\infty}^{+\infty} e^{\lambda(1-\alpha)\omega} f(\omega)d\omega}$ (25)

Bid competition: $n\int_{c_1}^{c_h} \frac{\int_{c^{*}_{i}}^{c_h} e^{-\lambda(1-\alpha)(c-c^{*}_{i})}(c-c^{*}_{i})[1-G(c)]^{n-2} g(c)dc}{\int_{c^{*}_{i}}^{c_h} e^{-\lambda(1-\alpha)(c-c^{*}_{i})} g(c)dc} [1-G(c^{*}_{i})]^{n-1} g(c^{*}_{i})dc^{*}_{i}$ (26)

McAfee and McMillan assume, for simplicity, that bidders are risk neutral. Then, the government solves for the optimal α with the following simpler function:

$$0 = \frac{\alpha}{h''(h'^{-1}(1-\alpha))} - n\int_{c_l}^{c_h}\int_{c^*_i}^{c_h}[1-G(c^*_i)]^{n-1}g(c^*_i)dc^*_i. \tag{27}$$

In this case, the government finds only two effects:

$$\text{Moral hazard: } \frac{\alpha}{h''(h'^{-1}(1-\alpha))}. \tag{28}$$

$$\text{Bid competition: } n\int_{c_l}^{c_h}\int_{c^*_i}^{c_h}[1-G(c^*_i)]^{n-1}d\alpha G(c^*_i)dc^*_i. \tag{29}$$

Equation (24) shows the moral hazard effect. I assume $h'' \geq 0$ and $h''' \geq 0$, so that there are decreasing returns to any cost reduction efforts. Recall from equation (13) that the values of $h(\epsilon_i)$ and ϵ_i decrease in α, and thus $h''(\epsilon_i)$ increases in α, since $h''' \geq 0$. As α increases, the moral hazard effect rises. This means that as the government shares more of an overrun with a firm, the firm will decrease its cost reduction effort.

The second term in (23) represents risk sharing effects (which is not a factor in the risk neutral case). This term depends on a risk measure, λ, and ω. In equation (25). As α rises, bidders share more cost overruns with the government. This is important to risk averse bidders, who do not have to include as large of a contingency amount in their bids for unpredictable conditions as with an FFP contract. Thus, the risk sharing effect lowers government payments as α increases.

The bid competition effect arises from the fact that cost-based reimbursement differentially subsidizes high and low cost bidders. As α increases, high cost bidders receive a larger payment than low cost bidders. Thus, if the government reimburses the firms at a higher rate, the high cost bidders have a greater subsidization of their costs. This encourages the high cost bidders to lower their bids to compete for the contract award, which in turn forces the low cost bidders also to reduce their bids, which decreases government expenditures.

The optimal contract balances the three effects and satisfies (23).

4.6 THE MCAFEE AND MCMILLAN MODEL AND MILITARY CONSTRUCTION

This section details the application of the McAfee and McMillan model to the Air Force military construction program data. The results of this section allow me to simulate the use of FPI contracts on the construction program. First, I discuss and defend the use of an assumption of a uniform probability distribution of bidder estimated costs and a normal distribution of error terms. Second, I modify this model to include an assumption about risk averse bidders.

4.6.1 MODEL APPLICATION TO MILITARY CONSTRUCTION

The model used in this section makes several assumptions. These include:

1). All bidders are assumed risk neutral.

2) The bidders' estimated costs are drawn from a uniform probability distribution.

3). The government uses a first price sealed bid auction for the contract award.

4) The project's unexpected cost disturbance function, $F(\omega)$, is normally distributed.

5) The moral hazard rate for incentive contracts assumes a cost difference of 5 - 20 percent of contract value between firm fixed and cost plus contracts.

A more detailed description of these assumptions follows.

In this section, I assume that all firms are risk neutral ($\lambda = 0$). Without this assumption, one needs to measure or calculate λ values for each bidder. If I could measure λ consistently and accurately among all bidders, then I could use equation (19) to calculate α and, eventually, τ. The military construction data provides few

clues to estimate λ values for all bidders. Additionally, if one could interview all bidders, assuming the bidders allow such interviews, how does one measure λ for the construction data in the database? Many firms may be out of business, under new management, or have merged with other firms. These actions can significantly alter the measurement of λ. If $\lambda > 0$, the risk-sharing effect should act to reduce payments, and therefore savings relative to the risk neutral case and FFP contract would increase. Using $\lambda = 0$ is a more conservative approach, since only the bid competition and moral hazard effect are used in the model.

For this simulation, the model assumes the bidders' estimated cost function, $G(c)$, follows a uniform probability distribution. Although one cannot justify this assumption on purely economic reasoning, one can justify its use on empirical grounds. The contract data contains the lowest, second lowest, and highest bids (for FFP contracts). I use these contract observations to show how the assumption about a uniform probability distribution is consistent with the data.

A possible method to explore this question involves calculating a hypothetical second lowest bid based on the uniform probability distribution and comparing it to the actual second lowest bid. Since the contract data includes the range of bids and number of bidders, I estimate the uniform interval between bids. This estimated interval, added to the lowest actual bid, yields an estimate of the second lowest bid. If they follow a uniform probability distribution, then there should be no statistically significant difference between the actual and hypothetical bids. While this comparison does not absolutely prove or disprove the assertion that the bids reflect a uniform probability distribution, it shows whether the data is consistent with the assumption about the use of a uniform probability distribution or not.

Two statistical tests were conducted on the differences between the actual and estimated bids. For the tests, the differences were assumed to follow a normal distribution. Additionally, the statistical tests use a pooled variance to calculate the appropriate standard error. The first test compares the difference in means between the actual lowest and second lowest bid for the actual and estimated bids. The difference between means provides a test for the second lowest bid. The null hypothesis is that there is no difference between the bids. The second test explores the percentage difference between the actual and

estimated bids. I use z tests to evaluate both hypotheses. The total number of contracts examined was 1213.

The results of the first test fail to reject the null hypothesis that the difference in means is 0. The test was made using a 10 percent significance level. The first and second lowest bid reflect values consistent with a uniform probability distribution. The results of the first test add support to the assertion that the bids follow a uniform probability distribution.

The second test, involving the percentage differences between actual and estimated second lowest bids, shows results similar to the first test. Specifically, I test if the percentage difference between the lowest and second lowest bids (actual and estimated) is the same. The test results lead one not to reject the null hypothesis that the percentage difference between the actual and hypothetical bids was 0.

The bids that were openly competed provide the least difference between the actual and estimated bids. The difference was .03 percent (essentially 0) with a SE of .49 percent. Conversely, the small business set asides have a mean percentage difference of .31 percent with a SE of .51 percent. Again, the statistical test for the difference between means shows that one cannot reject the hypothesis that the percentage difference between means is 0 (at a 1 percent significance level). This shows that the contracts, whether openly competitive or small business set asides, are consistent with a uniform probability distribution between the first and second lowest bids. Therefore, one can use the uniform probability distribution for both openly competitive and small business set asides.

The percentage difference between actual and hypothetical bids does not diverge much among different construction project types. All contract types, except medical facilities, have results that suggest one fails to reject the hypothesis that the percentage difference between the means was 0. However, if one uses a 5 percent statistical significance level to evaluate medical facilities, one can reject the hypothesis that the difference in means is 0. This category of projects has the highest standard error of all project types. Additionally, the medical facilities projects have the highest government estimated cost of completion and bids compared to any other project type. This may reflect the complexity of building these projects and the inherent risk of cost overruns

associated with this construction to the bidders. Nevertheless, I will use a uniform cost distribution in this model.

In addition, contracting officers from the Air Force, COE, and NAVFAC, who award contracts for Air Force military construction projects, have provided anecdotal evidence to support using a uniform probability distribution of bids. These contracting officers award military construction contracts in most of the 45 states having these projects and for all types of construction projects. I frequently heard that the bid pattern was more "evenly spaced out" rather than being skewed toward a particular point such as the median or extreme bid. Also, they made a point of emphasizing that the bids did not center around a "middle" bid (this seems to discount a *normal* probability distribution). A contracting officer on the staff of the Office of the Secretary of the Air Force noted that unlike many research and development contracts that have a bid pattern skewed to the lowest bid, the construction contract bids reflect a uniform probability distribution. The research and development contract bid pattern may reflect the increased interaction between the government and firms on specifications before formal bidding.

Of the 38 contracting officers I contacted by telephone, 27 mentioned that the bids seemed more evenly distributed among a range of bids rather than skewed to the highest, lowest, or mean value. This bid represents the bidder's lowest estimated cost for the project. Five contracting officers believed the bids were centered along a mean value. Four contracting officers thought the bid distribution was skewed toward the lowest bids. The remaining two contracting officers could not decide what the bid pattern most resembled. The consensus of these contracting officers supports the assertion that the military construction contract bids display a uniform probability distribution.

Another assumption involves the government use of a first price sealed bid auction. The government, at contract award, selects the contractor with the lowest sealed bid. This is the contract award auction technique used in FFI contracts for military construction. The firms do not have the opportunity to resubmit bids or negotiate their bids or the proposed α with the government. This is consistent with McAfee and McMillan.

The next assumption deals with the distribution of ω. $F(\omega)$ is assumed to be normally distributed. Recall, ω represents random, unpredictable costs that a firm incurs after it receives a contract award.

I use the normality assumption for several reasons. The value of ω represents the combined effects of many influences. If one assumes that these influences are independently distributed and random, then by the central limit theorem, the distribution approaches the normal as the number of variables increases. Also, if the data appears symmetric and relatively concentrated around a value (i.e., 0) the normal distribution will adequately represent the data even with a small sample size.[2] Lastly, the normal distribution only requires a mean and variance to specify it and it is a well known distribution.

There are several values available for a moral hazard rate or h_0. Recall, the problem of moral hazard is that one party to a contract or agreement may take actions that affect the other party's payoff, and that the second party cannot monitor the action. Some studies, using DoD contract awards, calculate the moral hazard rate based on the difference in government payments between an FFP and a CPFF contract (δ) for identical products.

The possible values for h_0 from these studies range from 5 to 20 percent. This means a product manufactured under an FFP contract results in costs 5 to 20 percent lower due to cost reduction efforts than if it were procured under a CPFF contract. Hiller and Tollison cite a GAO study made in the 1960s that estimate the cost "inefficiency" between the two contract types at 5 percent.[3] This seems low considering the nature of the projects bought under a cost reimbursement contract (e.g., high technology weapon systems with much risk of cost or schedule slippage), although a contracting expert in the Office of the Secretary of the Air Force thought 5 percent was reasonable for military construction projects.[4] In fact, for military construction projects, several contracting officials thought the moral hazard rate should not exceed 10 percent and thought 5 percent was a good

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[2] See Canavos, Applied Probability and Statistical Methods, p. 214.

[3] See Hiller and Tollison, "Incentive Versus Cost-Plus Contracts in Defense Procurement", p. 242.

[4] Interview with the Office of the Secretary of the Air Force's Contract Administration and Pricing Division, 15 July 1991.

estimate.

Two studies asserted that the value of h_o corresponds to a 10 percent cost difference.[5] Scherer and Moore both state that the value of h_o was 10 percent, although both studies had difficulty trying to find identical products contracted for under FFP and CPFF conditions.

McAfee and McMillan assume a value of 15 percent.[6] They develop this value by using several observations in different industries to represent government contracts. They make an analogy between h_o and cases under a regulated firm and natural monopoly. If the firm is regulated by the government, the government may agree to allow the firm solely to operate a business and charge a price greater than its cost. The government guarantees that the firm can charge its cost and a fixed fee (or percentage of its cost) to the public. The situation seems similar to a cost reimbursement contract since the firm can pass on costs to an individual consumer and still receive the fixed fee. The firm has little motivation to reduce costs. If the firm acts as a natural monopoly and is allowed to maximize profit, it solves for an optimal quantity and price to maximize profit. The firm would sell a finite quantity at a fixed price. This situation is like an FFP contract where firms increase profits by becoming more cost efficient.

McAfee and McMillan cite studies regarding the increased production costs due to regulation in the airline, electricity, telecommunications, and health care industries. The US electrical utilities industry costs, under regulation, are 10 percent higher compared to non-regulated costs from natural monopoly firms producing electricity. They also estimate the difference between pre-paid medical group plans and cost reimbursement insurance plans. Under a full cost reimbursement system, a doctor lacks motivation to reduce the patient's medical costs and could use medical facilities and services inefficiently. Conversely, under a pre-paid system a physician gets a fixed amount to treat a patient and has great motivation to reduce his medical costs as much as possible. The pre-paid insurance policy is like an FFP contract. The average difference in costs, from

[5]See Scherer 1964(a), "The Theory of Contractual Incentives for Efficiency", p. 264 and Moore, "Incentive Contracts", p. 241.

[6]See McAfee and McMillan 1988(a), Incentives in Government Contracting, p. 67.

four studies, was 20 percent.[7]

These different h_o values provide a range for the study. The simulation uses cases where h_o equals 5, 10, 15, and 20 percent. The 20 percent value seems too high for construction, but is used anyway as an upper extreme bound. Medical diagnosis and care have much more uncertainty regarding cost overruns than construction costs. The 10 percent level reflects the acquisition of weapon systems and other DoD projects, a much more risky situation for a contractor to complete on time and within cost than construction projects. So, I will focus on 5 and 10 percent moral hazard results the most.

4.6.2 APPLYING THE MODEL WITH A UNIFORM PROBABILITY DISTRIBUTION OF BIDS

In order to simulate the effects of a uniform probability distribution of bids, I must modify the McAfee and McMillan incentive contract. Using a uniform probability distribution, the value of G(c) is:

$$G(c) = \frac{c - c_l}{c_h - c_l}, \quad \text{where } c_h > c > c_l > 0 \tag{30}$$

The values c_l and c_h represent the range of possible project costs. McAfee and McMillan develop the expected profits for the winning bidder under a uniform probability distribution:[8]

$$E(\pi_1) = (1 - a)(1 - G(c^{*}_1))^{-(n-1)} \int_{c^{*}_1}^{c_h} (1 - G(c))^{(n-1)} dc \tag{31}$$

$$= \frac{(1 - a)(c_h - c^{*}_1)}{n} \tag{32}$$

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[7] Ibid. p. 6-5

[8] Ibid. p. 4-23

Recall from equation (11), that $\pi_i = (1 - \alpha)(b_i - c^*_i - \omega) + [\epsilon_i - h(\epsilon_i)]$. If firms are risk neutral, then the firms do not consider ω (since $E(\omega) = 0$). This changes equation (11), given uniform costs, to:

$$E(\pi_i) = (1 - \alpha)(b_i) - (1 - \alpha)(c^*_i) + [\epsilon_i - h(\epsilon_i)]. \tag{33}$$

Equating (32) to (33) yields:

$$\frac{(1 - \alpha)(c_h - c^*_i)}{n} = (1 - \alpha)(b_i) - (1 - \alpha)(c^*_i) + [\epsilon_i - h(\epsilon_i)]. \tag{34}$$

Rearranging (34) produces:

$$(1 - \alpha)(b_i) + [\epsilon_i - h(\epsilon_i)] = (1 - \alpha)(c^*_i) + \frac{(1 - \alpha)(c_h - c^*_i)}{n}, \tag{35}$$

$$= (1 - \alpha)\left(\frac{c_h}{n} + \frac{(n - 1)(c^*_i)}{n}\right) \tag{36}$$

Equation (36) shows the relationship of the payment based on the bid and cost reduction efforts to expected bidder costs. As α and n rises, the $E(\pi_i)$ falls.

The government's expected contract payment is:[9]

$$E(\tau) = \int_{c_1}^{c_h} (E(\pi_i) + c^*_i) n(1 - G(c))^{n-1} g(c) dc, \tag{37}$$

$$= E(c^*_i) + (1 - \alpha)\int_{c_1}^{c_h} \frac{(c_h - c^*_i)^{(n-1)}}{(c_h - c_1)} dc - [\epsilon_i - h(\epsilon_i)]. \tag{38}$$

[9]Ibid., p. 4-24.

Since the winning firm is the lowest cost bidder, the minimum expected cost on the project is:

$$c_{min} = \frac{n}{n+1}(c_l) + \frac{1}{n+1}(c_h). \tag{39}$$

Conversely, the maximum expected cost is:

$$c_{max} = \frac{1}{n+1}(c_l) + \frac{n}{n+1}(c_h). \tag{40}$$

McAfee and McMillan assume h is a quadratic function and $h'' = h_o$. According to McAfee and McMillan, the model uses a quadratic h function for tractability reasons since it is the simplest strictly convex function.[10] They simplify (38) as:[11]

$$E(\pi) = \frac{n}{n+1}(c_l) + \frac{1}{n+1}(c_h) + \frac{(1-\alpha)}{n+1}(c_h - c_l) - \frac{(1-\alpha^2)}{2h_o} \tag{41}$$

Note that to minimize $E(\pi)$, one needs to estimate c_l and c_h, know n, and choose an α value. Data about bid amounts and number of firms provide a way to estimate values for c_h and c_l. I then substitute the values of c_h and c_l into $E(\pi)$. The model also uses a value of k_i, which represents the net reduction in the firm's cost due to cost reduction efforts $((1-\alpha)\epsilon_i - h(\epsilon_i))$.

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[10]Ibid, p. 4-17.

[11]Ibid, p. 4-25.

$$(1-\alpha)b_{min} + k_i = (1-\alpha)\left(\frac{n}{n+1}(c_l) + \frac{1}{n+1}(c_h)\right) + k_i. \quad (42)$$

$$= \frac{(1-\alpha)}{n+1}[(n-1)c_l + (2)c_h] + k_i. \quad (43)$$

$$(1-\alpha)b_{max} + k_i = (1-\alpha)\left(\frac{1}{n+1}(c_l) + \frac{n}{n+1}(c_h)\right) + k_i. \quad (44)$$

$$= \frac{(1-\alpha)}{n(n+1)}[(n-1)c_l + (n^2+1)c_h] + k_i. \quad (45)$$

Equations (42) to (45) show the relationship between bids and expected costs. Solving (39) and (41) for c_h and c_l results in:

$$c_l = [b_{min} - \frac{2n(b_{max} - b_{min})}{(n-1)^2}] + k_i. \quad (46)$$

$$c_h = [b_{max} - \frac{(b_{max} - b_{min})}{(n-1)}] + k_i. \quad (47)$$

I then estimate costs by using the historical low and high bids, number of bids, α, and a cost reduction measure, $\frac{\varepsilon_i - h(\varepsilon_i)}{(1-\alpha)}$.

Given that the moral hazard function h is quadratic, then:[12]

$$\varepsilon = \frac{1-\alpha}{h_o}, \quad (48)$$

$$h(\alpha) = \frac{(1-\alpha)^2}{2h_o} = k_i. \quad (49)$$

Note that equation (49) is now a function of α and not ε. McAfee and McMillan define $h(\alpha)$ equal to k_i.

[12]Ibid, p. 4-25

The value of $h(\alpha)$ is found by evaluating the percentage difference between an FFP and cost plus contract (using McAfee and McMillan's base of c_h), δ. This function is:

$$\delta \equiv \frac{c_i \mid_{\alpha=1} - c_i \mid_{\alpha=0}}{c_h}, \tag{50}$$

$$= \frac{(c_i + \omega - \epsilon_i)|_{\alpha=1} - (c_i + \omega - \epsilon_i)|_{\alpha=0}}{c_h}, \tag{51}$$

$$= \frac{\left(c_i + \omega - \frac{1-\alpha}{h_o}\right)|_{\alpha=1} - \left(c_i + \omega - \frac{1-\alpha}{h_o}\right)|_{\alpha=0}}{c_h}, \tag{52}$$

$$= \frac{-\left(-\frac{1}{h_o}\right)}{c_h}, \tag{53}$$

$$= \frac{1}{c_h h_o} \quad \text{or } h_o = \frac{1}{\delta c_h}. \tag{54}$$

From (49) and (54) I define the net reduction in the firms's cost due to cost reduction efforts as:

$$k_i = \frac{\delta c_h (1 - \alpha)^2}{2} \quad \text{and} \tag{55}$$

$$c_i = [(c_{max} + (\frac{(b_{max} - b_{min})}{n - 1})]/[(1 - \frac{\delta}{2})],$$

$$c_h = b_{min} - \frac{2n(b_{max} - b_{min})}{(n - 1)^2} + \frac{\delta c_h}{2}.$$

Substituting (55) into (41) produces a new equation for $E(\tau)$. For clarity I define $E(\tau)$ in terms of c_h and c_1. The new equation is:

$$E(\tau) = c_1 + \frac{2 - \alpha}{n + 1}\left(c_h - c_1\right) - \frac{(1 - \alpha^2)}{2\left(\frac{1}{\delta c_h}\right)}. \tag{56}$$

Finding first order conditions (to solve for the minimum) for equation (56), $\frac{dE(\tau)}{d\alpha}$, results in:

$$\frac{dE(\tau)}{d\alpha} = \frac{-1(c_h - c_1)}{n + 1} - \frac{(-2\alpha)c_h\delta}{2} = 0, \tag{57}$$

$$= -\frac{c_h - c_1}{n + 1} + \alpha c_h \delta. \tag{58}$$

$$\alpha^* = \frac{c_h - c_1}{n + 1}\left(\frac{1}{c_h\delta}\right) \tag{59}$$

Equations (56) and (59) provide the minimum estimated payment and optimal share rate for the project. These results solve for $E(\tau)$ and the optimal α from bid information.

In summary, using the assumed values for δ, I can solve for the optimal α and $E(\tau)$. First, I calculate values for c_h and c_1 using equations (46) to (49). I use the optimal α to solve equation (56) and find $E(\tau)$. I then calculate the difference between the actual FFP contract cost (represented by the lowest bid) and the estimated payment to find relative savings based on an FPI contract award.

I then use these simulation results to help determine whether the government should use FPI contracts for military construction projects. However, these estimated payments cannot prove the actual cost savings or overruns are caused by the use of FPI contracts. They do provide strong evidence, given the model and assumptions, that the government can use incentive contracts. The simulation results can provide a forum to discuss the possible use of FPI contracts. This research can aid the Air Force in thinking about the use of these types of contracts in military construction projects and other projects where FFP contracts dominate.

4.6.3 RISK AVERSION

So far, the model has not considered risk aversion for the application to military construction. The measurement of a firm's risk aversion is difficult, as noted earlier. I use McAfee and McMillan's constant absolute risk utility function to evaluate how risk aversion changes $E(\pi)$, π, and α. Under this assumption, the firm's utility is:[13]

$$U = \frac{1 - e^{-\lambda x}}{\lambda}, \lambda \geq 0 \text{ (where } \lambda = 0 \text{ for risk neutral firms).} \qquad (60)$$

This function is the same as (45).

Constant absolute risk aversion means that the degree of risk aversion for all dollar levels of possible income (x) are the same. Thus there are no income effects in an individual's attitudes about risk. The firm prefers certain payments to uncertain payments with the same expected value. The difference between $E(\pi)$ and the certain payment the firm would take in trade is the risk premium.

McAfee and McMillan show that the utility cost to the firm, assuming a normal random distribution of ω, is:[14]

[13]Ibid. p. 4-7.

$$\psi(\alpha) = \int e^{\lambda(1-\alpha)\omega} f(\omega)d\omega. \tag{61}$$

I further simplify (61) by substituting the standard normal probability density function for $f(\omega)$:[15]

$$f(\omega) = \frac{1}{((\sqrt{2\pi})\ \sigma)} e^{-\frac{1}{2}z^2}, \tag{62}$$

$$z = \frac{x - \mu}{\sigma}. \tag{63}$$

Substituting $x = \lambda(1-\alpha)\omega$ and $\mu = 0$ into (63) simplifies $f(\omega)$. Equation (61) is solved with (62) and (63). The value of $\psi(\alpha)$ is:

$$\psi(\alpha) = \int e^{\lambda(1-\alpha)\omega} \frac{1}{((\sqrt{2\pi})\ \sigma)} e^{-\frac{1}{2}\left(\frac{\omega}{\sigma}\right)^2 + \lambda(1-\alpha)\omega} d\omega. \tag{64}$$

This simplifies to:

$$\psi(\alpha) = e^{[\lambda(1-\alpha)\sigma]^2/2}. \tag{65}$$

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[14]Ibid, p 4-11.

[15]See Canavos, Applied Probability and Statistical Methods, p. 123.

The dollar cost to the government of allowing the firm to accept the risk is $(-\frac{1}{\lambda}(\ln(\psi(\alpha)))$.[16] Thus, the government minimizes this value along with the effects from bid competition and moral hazard to minimize government's expected payment with respect to α.

The marginal gain to the government of assuming the risk is (σ^2 represents the variance of the distribution of ω):

$$p(\alpha) = \frac{d}{d\alpha}\left(-\frac{1}{\lambda}(\ln(\psi(\alpha)))\right), \tag{66}$$

$$= \lambda(1-\alpha)\sigma^2. \tag{67}$$

One can add (65) to (56) to solve for the optimal τ. Conversely, one can add (67) to (57) to solve for an optimal α.

$$E(\tau) = c_1 + \frac{2 - \alpha}{n + 1}\left(c_h - c_1\right) - \frac{(1 - \alpha^2)}{2\left(\frac{1}{\delta c_h}\right)} + e^{[\lambda(1-\alpha)\sigma]^2/2}, \tag{68}$$

$$\frac{dE(\tau)}{d\alpha} = \frac{-1(c_h - c_1)}{n + 1} - \frac{(-2\alpha)c_h\delta}{2} + \lambda(1-\alpha)\sigma^2 = 0, \tag{69}$$

$$\alpha^* = \frac{\frac{(c_h - c_1)}{n+1} + \lambda\sigma^2}{(c_h\delta + \lambda\sigma^2)}. \tag{70}$$

---

[16] See McAfee and McMillan 1985(b), Incentives in Government Contracting, p. 4-11.

I can solve for the values of α and $E(\tau)$. However, I need values for λ and σ. *In this study, I use* $\lambda = 8.221 \times 10^{-7}$, *this value corresponds to a firm being* indifferent between a certain \$400,000 or a gamble of gaining \$1 million or nothing, which seems plausible, if a bit high (but represents an upper bound for λ), for construction firms. I use this simple gamble as an example of a firm's risk aversion. I could use a larger value for λ; this only increases the risk sharing effect.

Several private construction firms mentioned, in interviews, that they normally keep a 5 percent management reserve, based on their costs, for unpredictable contingencies (expected value of ω). I assume this represents one standard deviation, and thus I define the dollar value of σ as $.05\left(\frac{c_h - c_l}{2}\right)$. It is possible to vary the value of the management reserve from 5 percent (no firm admitted a management reserve greater than 5 percent). The Air Force normally keeps a 5 percent management reserve for unpredictable costs for military construction projects for budgetary reasons.

APPENDIX 4.1

Let $E\tau(c^*_i) = E(1 - \alpha)B(c^*_i) + \alpha C_i$ from (15)

$C_i = c^*_i + \omega - \epsilon_i$ from (1),

$\pi_i = (1 - \alpha)(b_i - c^*_i - w) + (1 - \alpha)\epsilon_i - h(\epsilon_i)$ from (8),

$b_i = B(c^*_i)$.

Substitute $b_i = B(c^*_i)$ into (15).

$$E\tau(c^*_i) = E((1 - \alpha)b_i + \alpha C_i),$$

$$= E(b_i - \alpha b_i + \alpha C_i). \qquad (A4.1.1)$$

Using (8), solve for b_i.

$$b_i = \frac{\pi_i - (1 - \alpha)\epsilon_i + h(\epsilon_i)}{(1 - \alpha)} + c^*_i + \omega. \qquad (A4.1.2)$$

Substitute (A4.1.2) and (1) into (A4.1.1)

$$E\tau(c^*_i) = E\left(\left(\frac{\pi_i - (1 - \alpha)\epsilon_i + h(\epsilon_i)}{(1 - \alpha)} + c^*_i + \omega\right) - \alpha\left(\frac{\pi_i - (1 - \alpha)\epsilon_i + h(\epsilon_i)}{(1 - \alpha)} + c^*_i + \omega\right) + \alpha\left(c^*_i + \omega - \epsilon_i\right)\right), \qquad (A4.1.3)$$

$$= E\left(\left(\frac{\pi_i - (1 - \alpha)\epsilon_i + h(\epsilon_i)}{(1 - \alpha)} + c^*_i + \omega\right) - \alpha\left(\frac{\pi_i - (1 - \alpha)\epsilon_i + h(\epsilon_i)}{(1 - \alpha)}\right) - \alpha\epsilon_i\right), \qquad (A4.1.4)$$

$$= E\left([1 - \alpha]\left(\frac{\pi_i - (1 - \alpha)\epsilon_i + h(\epsilon_i)}{(1 - \alpha)}\right) + c^*_i + \omega - \alpha\epsilon_i\right), \qquad (A4.1.5)$$

$$= E\left(\pi_i - (1 - \alpha)\epsilon_i + h(\epsilon_i) + c^*_i + \omega - \alpha\epsilon_i\right). \qquad (A4.1.6)$$

$$= E\left(\pi_i - \epsilon_i + h(\epsilon_i) + c^*_i + \omega\right). \tag{A4.1.7}$$

Earlier I assumed $E(\omega) = 0$. The values ϵ_i and c^*_i are unknown to the government and treated as estimates. Therefore, one solves for:

$$E(\tau(c^*_i)) = E(\pi_i) + c^*_i + [h(\epsilon_i) - \epsilon_i]. \tag{A4.1.8}$$

APPENDIX 4.2

Find $E(\pi_i(c^*_i))$:

Using $U(x) = \frac{1 - e^{-\lambda x}}{\lambda}$, first define $EU(x)$ considering ω in the calculation.

$$EU(x - (1 - \alpha)\omega) = \frac{1 - e^{-\lambda x}}{\lambda}\left(\int_{-\infty}^{+\infty} e^{\lambda(1-\alpha)\omega}f(\omega)d\omega\right), \qquad (A4.2.1)$$

$$= \frac{1}{\lambda}\left(1 - e^{-\lambda x}\left(\int_{-\infty}^{+\infty} e^{\lambda(1-\alpha)\omega}f(\omega)d\omega\right)\right), \qquad (A4.2.2)$$

$$= \frac{1}{\lambda}\left(1 - \Psi(\alpha)e^{-\lambda x}\right). \qquad (A4.2.3)$$

$$\text{Let } \Psi(\alpha) = \int_{-\infty}^{+\infty} e^{\lambda(1-\alpha)\omega}f(\omega)d\omega. \qquad (A4.2.4)$$

To find the optimal $EU(\pi_i)$ with respect to c^*_i, solve for the first order conditions for (A4.2.1) with respect to x first (See McAfee and McMillan proof of Lemma 1):

$$EU'(x - (1 - \alpha)\omega) = (1 - \lambda EU(x - (1 - \alpha)\omega)). \qquad (A4.2.5)$$

Substitute $x = (1 - \alpha)(b_i - c^*_i - \omega) + (1 - \alpha)\epsilon_i - h(\epsilon_i)$ into (A4.2.1) for $EU(\pi_i)$ and find the first order conditions (recall $b_i = B(c^*_i)$):

$$\frac{dEU(\pi_i)}{dc^*_i} = EU'\left((1 - \alpha)(B'(c^*_i)) - (1 - \alpha)\right). \qquad (A4.2.6)$$

Using $(1 - \alpha)\frac{EU'(B'(c^*_i))}{EU} = \frac{(n - 1)g(c^*_i)}{1 - G(c^*_i)}$ rearrange (A4.2.5) as:

$$\frac{dEU(\pi_i)}{dc^*_i} = \left(\frac{(n - 1)g(c^*_i)}{1 - G(c^*_i)} EU - EU'(1 - \alpha)\right). \qquad (A4.2.7)$$

Equation (A4.2.7) shows how the bidder's behavior changes with relationship to c^*_i on $EU(\pi_i)$. Selecting the integral from c^*_i to c_l represents the utility from costs between c^*_i and the lowest possible cost. The solution for A4.2.7 (a linear ordinary differential equation) is:[1]

$$EU = [(1-G(c^*_i))]^{-(n-1)} e^{x(1-\alpha)c^*_i} [K - (1-\alpha)\int_{c_l}^{c^*_i} [1-G(c)]^{n-1} e^{\lambda(1-\alpha)c} dc. \qquad (A4.2.8)$$

The constant K represents the solution for (A4.2.6) and (A4.2.7) for the range of relevant costs. For ex ante utility for an individual bidder, one calculates:

$$EU = e^{x(1-\alpha)c^*_i} [K - (1-\alpha)\int_{c_l}^{c^*_i} [1-G(c)]^{n-1} e^{\lambda(1-\alpha)c} dc]. \qquad (A4.2.9)$$

If $c^*_i = c_h$ then EU = 0 (won't get the contract award). The bid c_h $(B(c_h))$ has a much lower chance of winning the contract award (unless the firm is the only bidder). Conversely, if the firm bids lower than c^*_i, then the firm will bid lower than it should to cover costs. The firm should consider bidding based on costs from c_h and c^*_i. Therefore, one needs to find the difference between c_h and c^*_i. This represents the estimated costs that a bidder can use to make bids that can result in an ex ante profit for the project. Solving for K allows the government to observe the bidder's behavior based on estimated costs.

$$K = (1-\alpha)\int_{c^*_i}^{c_h} [1-G(c)]^{-(n-1)} e^{\lambda(1-\alpha)c} dc]. \qquad (A4.2.10)$$

[1]See McAfee and McMillan 1986(a), p. 336.

Therefore, one uses the following EU function:

$$EU = [1-G(c^*_i)]^{-(n-1)} e^{\lambda(1-\alpha)c^*_i}(1-\alpha)\int_{c^*_i}^{c_h}[1-G(c)]^{n-1}e^{-\lambda(1-\alpha)c}dc. \qquad (A4.2.11)$$

McAfee and McMillan rearrange (A4.2.11) to get:

$$EU = \frac{1}{\lambda}[1-[1-G(c^*_i)]^{-(n-1)}\int_{c^*_i}^{c_h}e^{-\lambda(1-\alpha)(c-c^*_i)}(n-1)[1-G(c)]^{n-2}g(c)dc]. \qquad (A4.2.12)$$

Using $\pi_i = (1 - \alpha)(b_i - c^*_i - \omega) + (1 - \alpha)\varepsilon_i - h(\varepsilon_i)$ and $U(x) = \frac{1 - e^{-\lambda x}}{\lambda}$, set $U(\pi_i)$ equal to EU from (A4.2.12). For $U(\pi_i)$ use (A4.2.1) for, considering ω, and substituting π_i for x. Solving this function results in:

$$e^{-\lambda[(1-\alpha)B(c^*_i)-(1-\alpha)c^*_i-(1-\alpha)\varepsilon_i-h(\varepsilon_i)]}$$

$$= \frac{[1-G(c^*_i)]^{-(n-1)}}{\int_{-\infty}^{+\infty}e^{\lambda(1-\alpha)\omega}f(\omega)d\omega}\int_{c^*_i}^{c_h}e^{-\lambda(1-\alpha)(c-c^*_i)}(n-1)[1-G(c)]^{n-2}g(c)dc). \qquad (A4.2.13)$$

Taking logarithms in (A4.2.13) and simplifying results in:

$$E(\pi_i(c^*_i)) = -\frac{1}{\lambda}[\ln(n-1) - (n-1)\ln(1-G(c^*_i)) - \ln\left(\int_{-\infty}^{+\infty} e^{\lambda(1-\alpha)\omega} f(\omega)d\omega\right) + \ln\left(\int_{c^*_i}^{c_h} e^{-\lambda(1-\alpha)(c-c^*_i)} (n-1)[1-G(c)]^{n-2} g(c)dc\right)]. \qquad (A4.2.14)$$

V. SIMULATION RESULTS

In this chapter, I estimate the hypothetical FPI contract payments and compare them to actual FFP payments. I then determine whether the Air Force can save money by using FPI contracts. Additionally, I examine the optimal share rate that minimizes the Air Force's contract payment, and statistically test the significance of savings rates by various characteristics.

I evaluate these hypothetical savings and optimal share rates based on the same contract characteristics as presented in Chapter III. Specifically, I evaluate the size of savings and optimal share rates based on the following characteristics:

- Project type.
- Contract award type.
- Number of bidders.
- Geographical region.
- Moral hazard rate.
- Degree of risk aversion.

5.1 SAVINGS RATES

This section describes the relative hypothetical savings rates between the actual FFP contract payments and estimated FPI contract payments for Air Force military construction projects.

5.1.1 PAYMENT DIFFERENCES BETWEEN FIRM FIXED PRICE AND INCENTIVE CONTRACTS

The mean percentage difference between the actual FFP and estimated FPI payments has a range of 6.2 to 10.6 percent, depending on moral hazard rate

assumptions. See Table 5.1 for more details about these savings. These values represent a simple weighted mean savings calculation between the estimated optimal FPI payments and the lowest bid under the FFP contract.

Savings relative to the FFP contract decrease as the moral hazard rate increases. As moral hazard rates rise, firms have an increased incentive to pad their costs. The contracting officer should moderate this incentive by lowering the share rate, which makes the firm more responsible for its costs. Lowering the share rate makes the contract more like an FFP contract and thus, as moral hazard problems increase, optimal FPI contract payments are closer to an FFP contract payment and relative savings decrease.

How much do these relative savings rates differ as the moral hazard rate increases? I compare the project types' savings rates under different moral hazard rates and examine how they differ by their standard deviations (in terms of the precentage of savings) of these savings rates. For example, under a 5 percent moral hazard rate the savings rate was within two standard deviations (δ = 1.018 percent) of the mean savings rate under the 10 percent moral hazard rate (10.6 versus 8.2 percent savings). The other savings rates under the 10 percent (δ = 1.577 percent), 15 percent (δ = 1.628 percent), and 20 percent (δ = 1.859 percent) moral hazard rates were also within one standard deviation of each other. This implies that the sensitivity of these savings rates to moral hazard rates of 5 percent is small.

The contract award type also affects the savings rates. See Table 5.2. Savings are higher for 8(a) awards than IFB awards using a 5 percent moral hazard rate. Chapter III showed that 8(a) awards have fewer bidders than IFB awards. This, in part, explains why 8(a) awards have greater savings rates. A consequence of the model is that as the number of bidders rise, the optimal α value falls. This means the savings, relative to an FFP contract, are lower as the contract draws more bidders, because an FFP contract, by definition, sets α = 0. Thus, 8(a) awards, with fewer bidders, have greater savings.

Up to now, I have described the results in terms of contract award and project type. Contracting officers frequently use simple contract classifications to determine critical contracting decisions.[1] For example, many construction contracting officers use project types to classify military construction projects. I now compare how much the relative savings change by project type, depending on

such factors as contract size, contract award type, geographic region, and other considerations.

Under each of these considerations, the FPI contract payments are lower than FFP contracts. In an FPI contract, there are three effects at work: risk sharing, bid competition, and moral hazard. The key advantage to an FPI contract compared to an FFP contract is the exploitation of risk sharing and bid competition effects. See Figure 5.1. As the share rate rises from 0, these effects reduce payments to a point, α^*. Before α^*, the marginal benefit to risk sharing and bid competition overshadow the marginal cost of moral hazard. After surpassing α^*, payments rise due to the increasingly severe moral hazard effect. While using α^* can reduce Air Force payments, note that an inappropriately high α value can lower savings.

Figure 5.2 provides an example illustrating these concepts. This example is from a vehicle maintenance facility built during 1986 in Texas, and was an 8(d) competed project. Increasing the share rate reduces the projected government payment from the firm fixed price control to a point. At an optimal α value of 63 percent, the Air Force can make a minimum payment that lowers payments by 8.7 percent. If the contracting officer increases the optimal α, payments rise dramatically and eventually exceed the FFP contract payment.

5.1.2 SAVINGS BY PROJECT TYPE

I now examine weighted savings rates by project type. I first compare which project types have the highest and lowest savings rates. Second, I use statistical tests to determine if the savings rates significantly differ by project type.

See Table 5.2 for a description of weighted savings by project type and contract award type. The lowest savings were in the warehouse and storage and the living and personnel support facilities. For the warehouse and storage, the administrative, and the living and personnel support facilities, these projects may not have required as many stringent technical specifications and many of the builders who bid have experience with these types of facilities. These projects have a relatively low difference in bid range (i.e., the difference between c_h and

[4]Interview with the Air Force's Chief, Contract Administration Division, 18 Jul 1990

TABLE 5.1

WEIGHTED MEAN SAVINGS BETWEEN FFP AND FPI CONTRACTS

MORAL HAZARD RATES	PERCENT MEAN SAVINGS
5%	10.6%
10%	8.2%
15%	7.1%
20%	6.2%

TABLE 5.2

WEIGHTED SAVINGS RATES BY PROJECT TYPE

PROJECT TYPE

	100	200	300	400	500	600	700	800
FPI (5% MH)								
IFB	9.4	9.3	8.7	7.6	7.8	8.7	8.0	14.3
8(d)	10.4	10.3	10.2	11.6	12.6	8.0	9.0	14.9
Total	10.1	10.1	9.4	10.0	10.3	8.2	8.7	14.7
FPI (10% MH)								
IFB	8.0	7.8	7.6	5.8	5.7	6.9	6.2	11.2
8(d)	9.1	8.6	10.1	9.7	12.1	6.4	6.9	14.6
Total	8.8	8.3	9.3	7.1	9.2	6.6	6.7	14.0
FPI (15% MH)								
IFB	6.7	6.5	6.2	4.5	4.2	6.6	5.4	11.0
8(d)	8.3	8.0	9.7	9.1	10.8	5.4	6.0	12.4
Total	8.0	7.5	8.2	6.8	7.7	5.6	5.8	12.1
FPI (20% MH)								
IFB	5.5	5.4	5.6	3.8	3.1	6.0	4.9	10.1
8(d)	7.9	7.6	9.0	8.3	9.6	4.9	5.7	12.2
Total	7.3	7.1	7.5	6.1	5.1	5.2	5.3	11.7

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

FIGURE 5.1

GOVERNMENT PAYMENT VS. SHARE RATE (α)

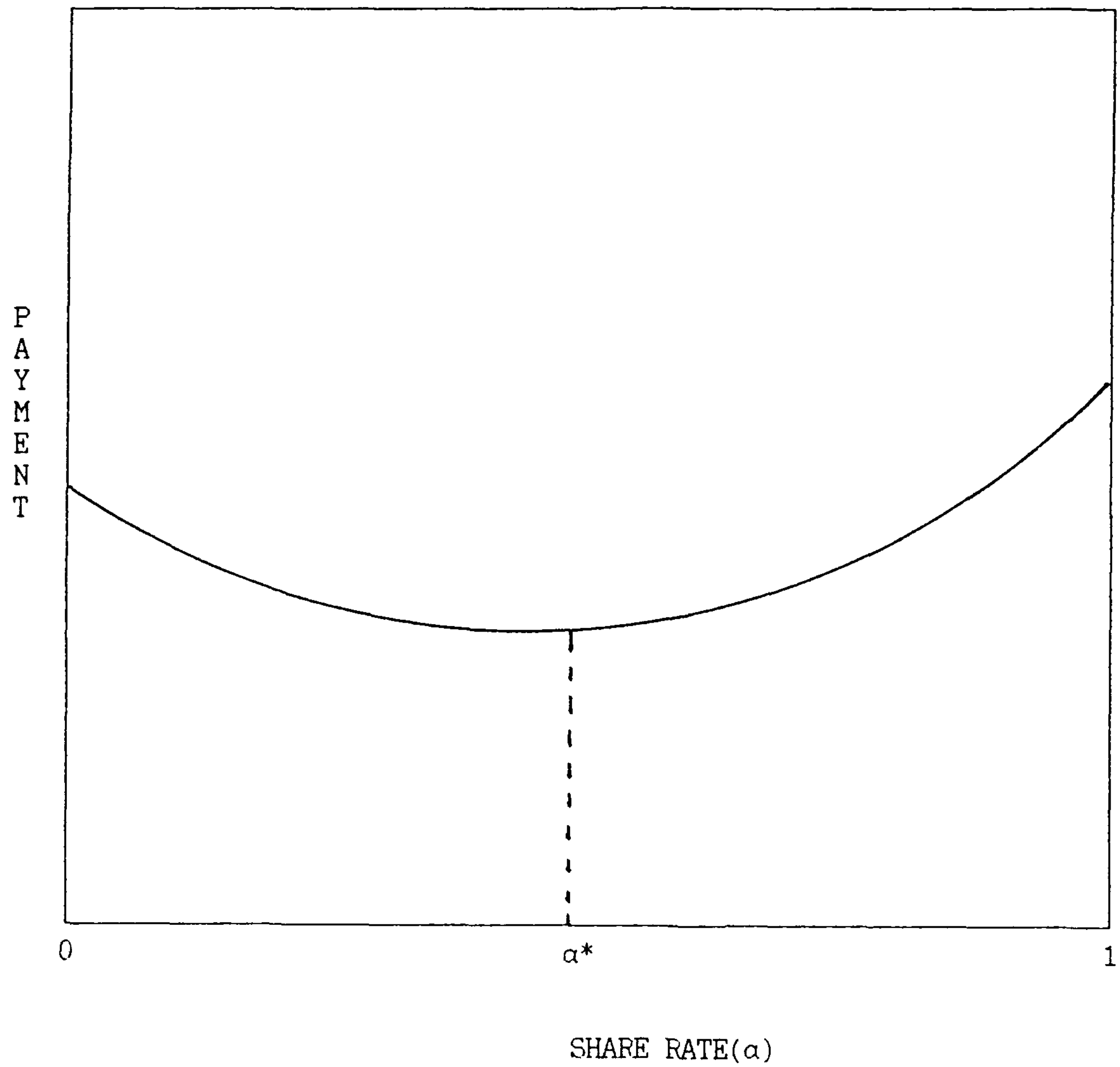
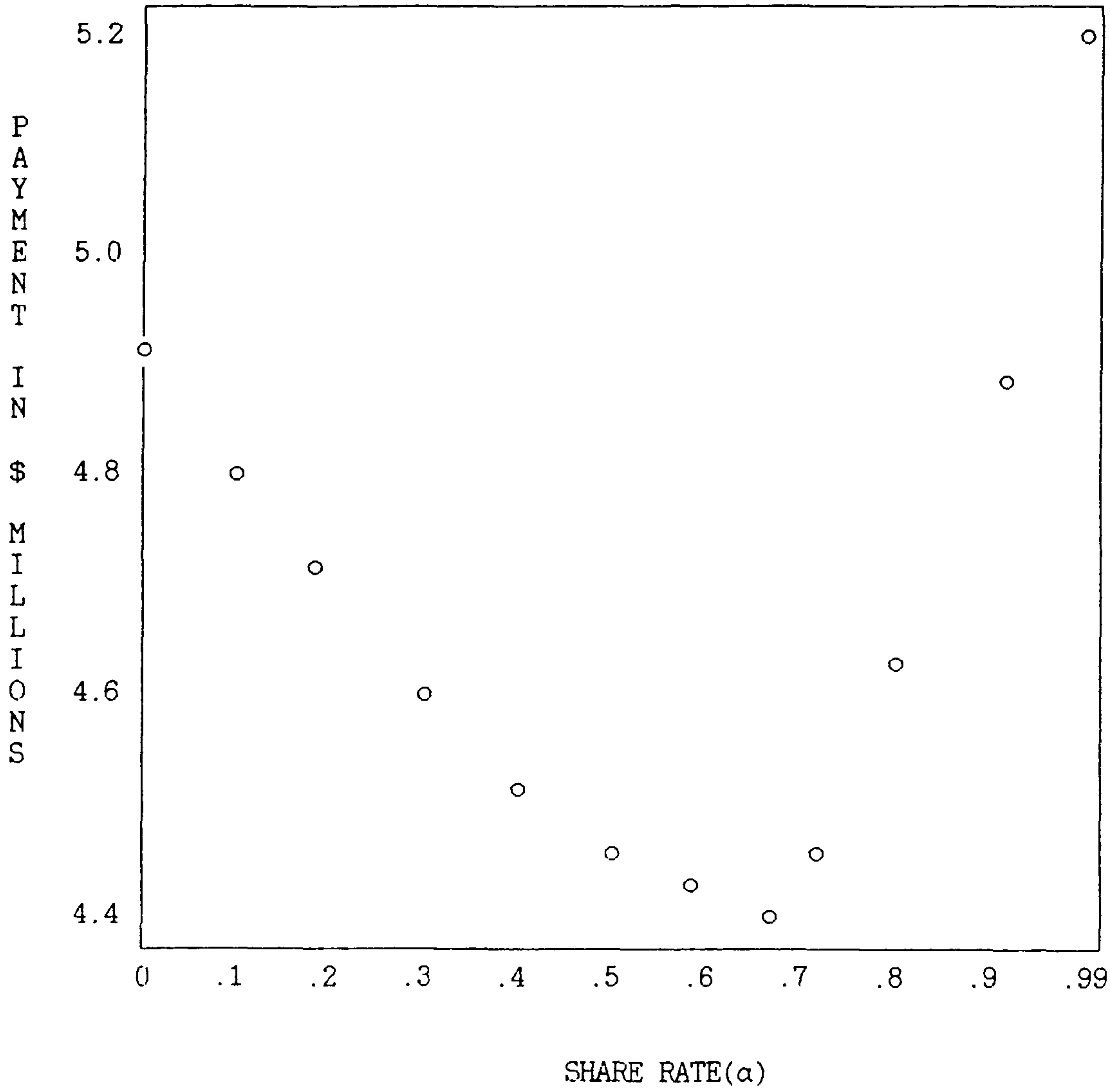


FIGURE 2

PROJECT PAYMENT VS. SHARE RATE (α)



c_l) as reflected in their coefficient of variation values (see Table 3.8, Coefficient of Variation in Chapter III). Some civil engineers said that these project types are very similar to many civilian projects and attract many firms willing to bid on these projects. The smaller savings rates may reflect the competition that has already taken place between the bidders under FFP contracts. If the range between c_h and c_l is small and many bidders participate in the contract competition, the Air Force loses little from using an FFP contract.

I now test whether the savings rates across project types were statistically different. This series of tests compares the equality of each mean high savings rate to each mean low savings rate by project type. For example, I test the medical facilities project types against the warehouse and storage projects. Under this series of tests, I find that the savings for all projects are not significantly different at the 10 percent level.

An explanation for these differences involves the relative range between c_h and c_l (as reflected in bid amounts) and number of bidders. Wide cost distributions and a lower number of bidders mean higher share rates relative to other contracts. This means that compared to FFP contracts, the savings are high due to the savings generated by the bid competition effect. For example, using the 5 percent moral hazard rate assumptions, the savings are 10.3 and 14.7 percent for the medical and the utilities and energy projects respectively. Notice in Table 3.8, Chapter III, that the coefficient of variation for project types reflects a high variance of 10.48 percent for the medical facilities and 13.46 percent for the utilities and energy projects, and consequently these contracts have higher savings rates than other projects (all other project types average less, about 8 percent). The utilities and energy and the medical facilities projects also have fewer bidders, on average, than other project types (average number of bidders for all projects is 7.6, 6.7 for the utilities and energy projects and 6.5 bidders for medical facilities). These projects have stringent technical specifications and may require special equipment not seen in typical construction jobs. This may cause a wider variance in the range of expected costs and fewer bidders.

5.1.3 SAVINGS RATES BASED ON PROJECT TYPE AND CONTRACT AWARD

In this section, I compare weighted savings rates based on contract award

methods.

Notice in Table 5.2 that there are differences in savings rates between the project types based on contract award types. For example, the 8(d) awards have greater savings rates than IFB awards for some facility projects. Recall, that the 8(d) awards are competed among a selected group of firms (small, disadvantaged businesses) that limits the total number of bidders for the contract; which may explain why savings rates are higher than with IFB awards. IFB awards compete among all qualified firms and this could affect the bids and savings rates in several ways. First, the IFB awards attract more bidders than 8(d) awards. Then the share rates are probably lower and the optimal contract for IFB contracts look more like an FFP contract and thus savings rates should be lower for IFB awards. One also might see less variability in the IFB bids which also lowers share rates. In general, 8(d) contract awards have greater coefficient of variation values than IFB awards. This means the range of bids (and expected costs) are greater and savings should rise.

FPI contracts awarded under 8(d) conditions have a weighted 11.3 percent savings (assuming a 5 percent moral hazard rate). IFB awards have a mean 10.0 percent savings rate under the proposed incentive contracts. The difference in savings rates seems moderate. A t-test of the difference between mean savings rates for IFB and 8(d) contracts shows that they do not differ at the 5 percent significance level.

5.1.4 SAVINGS RATES BY MORAL HAZARD RATES AND NUMBER OF BIDDERS

The FPI contract payment under the McAfee and McMillan model relies on the moral hazard rate and the number of bidders. As the number of bidders and the moral hazard rate rises, the model specifies that savings rates decrease. See Tables 5.3 to 5.7 for evidence of this observation in the simulation results. These results mirror the effects shown earlier in Chapter IV. See Table 5.8 for information on bidders by project and contract award types.

5.1.5 SAVINGS RATES BY GEOGRAPHICAL REGIONS

Now, I examine whether the location of the project affects savings rates.

TABLE 5.3

SAVINGS RATES BY PROJECT TYPE (BIDS ≤ 5)

PROJECT TYPE

	100	200	300	400	500	600	700	800
FPI (5% MH)								
IFB	10.9	10.3	9.3	9.7	11.2	9.8	8.9	15.7
8(d)	11.0	11.3	11.6	13.2	13.5	8.9	9.4	15.9
FPI (10% MH)								
IFB	10.5	10.2	8.3	7.9	9.7	9.2	8.2	13.2
8(d)	10.9	10.3	10.4	11.3	12.9	6.8	7.9	13.3
FPI (15% MH)								
IFB	9.9	9.7	6.8	6.4	7.2	7.8	6.6	11.5
8(d)	9.6	9.9	10.0	10.7	12.0	6.5	7.4	12.3
FPI (20% MH)								
IFB	8.8	7.6	6.1	6.3	4.3	7.3	6.3	11.0
8(d)	9.4	8.8	9.5	9.6	10.7	5.6	5.9	12.7

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

TABLE 5.4

WEIGHTED SAVINGS RATES BY PROJECT TYPE (5 < BIDS ≤ 10)

PROJECT TYPE

	100	200	300	400	500	600	700	800
FPI (5% MH)								
IFB	7.8	8.1	7.0	6.7	5.8	8.6	7.5	10.4
8(d)	9.5	8.6	8.9	10.6	11.9	7.5	7.6	12.5
FPI (10% MH)								
IFB	6.1	5.8	6.1	5.5	6.3	6.2	5.7	8.4
8(d)	6.9	6.7	8.3	10.1	9.3	5.6	5.8	9.6
FPI (15% MH)								
IFB	4.9	4.4	5.4	3.7	5.7	5.4	3.8	8.3
8(d)	5.3	5.5	7.9	6.7	7.5	4.3	5.0	9.3
FPI (20% MH)								
IFB	3.5	3.8	5.3	2.9	2.4	5.2	3.4	8.1
8(d)	5.3	5.3	7.6	6.5	4.1	3.9	4.7	8.8

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

TABLE 5.5

SAVINGS RATES BY PROJECT TYPE (10 < BIDS ≤ 15)

PROJECT TYPE

	100	200	300	400	500	600	700	800
FPI (5% MH)								
IFB	7.6	7.8	6.7	5.8	5.6	6.4	6.9	10.3
8(d)	8.7	8.5	n/a	7.8	8.6	6.3	7.5	11.8
FPI (10% MH)								
IFB	5.6	5.7	5.5	5.4	5.7	5.2	5.5	8.3
8(d)	6.5	6.4	n/a	7.7	8.0	5.1	5.7	9.2
FPI (15% MH)								
IFB	3.7	3.6	3.8	3.6	2.8	2.3	3.4	6.1
8(d)	4.7	4.5	n/a	7.6	6.5	2.5	4.8	6.6
FPI (20% MH)								
IFB	2.6	2.0	1.8	2.5	2.2	2.1	2.1	5.7
8(d)	3.7	2.5	n/a	6.5	3.5	2.3	2.8	6.3

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

TABLE 5.6

SAVINGS RATES BY PROJECT TYPE (15 < BIDS ≤ 20)

PROJECT TYPE

	100	200	300	400	500	600	700	800
FPI (5% MH)								
IFB	7.4	6.9	6.4	5.3	5.5	n/a	6.7	9.8
8(d)	8.6	8.4	9.0	7.2	n/a	n/a	7.4	10.6
FPI (10% MH)								
IFB	5.6	5.6	4.9	4.5	4.5	n/a	5.2	8.1
8(d)	6.4	6.3	7.7	7.4	n/a	n/a	5.4	9.1
FPI (15% MH)								
IFB	3.5	3.5	3.7	3.3	2.6	n/a	3.3	5.2
8(d)	3.8	4.1	5.5	7.6	n/a	n/a	4.2	6.3
FPI (20% MH)								
IFB	1.5	1.6	1.5	1.5	1.8	n/a	1.6	5.2
8(d)	1.7	2.4	2.1	6.2	n/a	n/a	1.9	5.8

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

TABLE 5.7

WEIGHTED SAVINGS RATES BY PROJECT TYPE (BIDS > 20)

PROJECT TYPE

	100	200	300	400	500	600	700	800
FPI (5% MH)								
IFB	7.3	6.6	n/a	n/a	n/a	7.5	n/a	9.5
8(d)	8.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a
FPI (10% MH)								
IFB	5.5	5.5	n/a	n/a	n/a	5.1	n/a	6.8
8(d)	6.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a
FPI (15% MH)								
IFB	3.3	3.3	n/a	n/a	n/a	3.3	n/a	4.3
8(d)	3.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
FPI (20% MH)								
IFB	1.4	1.5	n/a	n/a	n/a	2.1	n/a	1.9
8(d)	1.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

TABLE 5.8

NUMBER OF BIDDERS BY PROJECT TYPE

	PROJECT TYPE							
	100	200	300	400	500	600	700	800
AWARD TYPE								
IFB	8.4	9.2	7.6	8.0	9.3	9.0	8.6	9.3
8(d)	7.2	6.7	6.8	7.6	7.5	8.4	7.7	7.0

TABLE 5.9

WEIGHTED SAVINGS BY GEOGRAPHIC REGION

INCENTIVE CONTRACT

REGION	5% MH	10% MH	15% MH	20% MH
New England	11.0	7.3	6.9	5.8
Middle Atlantic	10.7	7.2	5.6	5.3
South Atlantic	10.8	7.3	6.1	5.6
East North Central	10.2	7.2	5.9	5.4
East South Central	10.2	7.2	5.9	5.4
West North Central	10.5	7.3	6.0	5.5
West South Central	10.7	7.3	6.1	5.6
Mountain	10.1	7.0	5.7	4.9
Pacific	9.8	6.6	5.8	4.6

This evaluation first describes savings based on geographic region alone and then by region and project type.

See Table 5.9 for a list of savings rates by geographic region and moral hazard rate. The weighted savings rates for construction projects using incentive contracts do not differ greatly by geographic region with a 5 percent moral hazard rate.

I use a one way ANOVA to test if the mean weighted savings are the same among geographical regions, and find that there is no difference at the 5 percent significance level.

I also test whether geographical regions had positive savings rates. If the geographical regions have positive mean weighted savings rates, the Air Force has more evidence to apply this contract type throughout the United States. To test these geographical regions, I determine whether, each mean weighted savings rate is positive. Using a t-test, the test results indicate that the mean weighted savings rates are all positive at the 1 percent significance level.

I now examine savings rates by region and project type. Table 5.10 shows savings rates under an incentive contract with a 5 percent moral hazard rate (other moral hazard rates have similar results) based on region and project type. These project types all had significant positive savings rates. These savings rates range from a low of 5.7 percent for the administrative and computer facilities in the New England area to a high of 16.4 percent for the utilities and energy projects in the Middle Atlantic region.

The precision of statistical comparisons between project types is reduced because some have only a few contracts awarded in that particular project type. Yet, there are some project types within regions that have savings rates that appear different from others. I use a two way ANOVA test to determine whether the mean savings rates were statistically equal among project types and geographical regions. The project types evaluated include: the administrative, the maintenance and logistics repair, and the utilities and energy projects. The test reveals that the mean savings rates are not significantly different among project types at the 1 percent significance level.

In general, these results support the application of incentive contract use throughout the United States without regard to geographical region. Since the FAR and other service procurement regulations do not restrict contract use

TABLE 5.10

WEIGHTED SAVINGS BY REGION & PROJECT TYPE (5% MH)

PROJECT TYPE

REGION	100	200	300	400	500	600	700	800
New England	10.4	8.4	10.5	6.0	5.7	6.4	6.8	14.1
Middle Atlantic	9.9	8.5	7.7	11.8	8.9	n/a	7.9	16.4
South Atlantic	9.6	10.4	10.1	9.5	14.3	9.1	9.3	14.4
East North Central	10.0	11.0	8.5	8.2	9.6	9.1	9.9	14.2
East South Central	9.9	8.4	11.4	8.1	9.7	5.2	5.9	14.5
West North Central	11.2	11.0	n/a	8.1	5.9	6.9	11.1	14.3
West South Central	11.0	10.9	11.9	10.6	13.2	9.3	8.4	14.7
Mountain	9.1	9.0	8.6	10.6	n/a	7.7	8.6	15.9
Pacific	9.4	9.2	9.1	7.7	7.1	6.3	9.1	14.8

geographically, this finding suggests that incentive contracts should be applied to military construction throughout the United States.

5.2 OPTIMAL SHARE RATES

In this section, I explore the estimated values of the optimal share rates. Table 5.11 presents mean optimal share rates based on moral hazard rate assumptions. In general, as the moral hazard rate increases, the Air Force should offer a lower α value. I now look at how the optimal α changes by contract award, project type, and number of bidders.

5.2.1 OPTIMAL SHARE RATES BY CONTRACT AWARD

See Table 5.12 for a summary of optimal share rates based on project type, contract award type, and moral hazard rate assumption. Optimal share rates are higher for 8(d) contract awards than IFB awards. The 8(d) awards have an average optimal share rate of 75.7 percent compared to 66.5 percent for the IFB awards. This may be caused by fewer bidders in the 8(d) awards than IFB awards. I test the hypothesis that 8(d) optimal share rates are greater than IFB optimal share rates, and find that share rates are greater for 8(d) awards than IFB awards at the 1 percent significance level.

5.2.2 OPTIMAL SHARE RATES BY PROJECT TYPE AND NUMBER OF BIDDERS

I now examine how share rates differ by project types in this section. See Table 5.12 for a breakdown of optimal share rates.

The highest share rate comes from the utilities and energy projects. Again, this project type has a relatively wide range in bids. As the expected cost difference increases, the Air Force can decrease its τ by increasing α to take advantage of the large bid competition effect. By subsidizing the higher cost firms at a greater rate (compared to an FFP contract), the Air Force forces the

TABLE 5.11

OPTIMAL SHARE RATES

5% MH	73.5%
10% MH	39.5%
15% MH	28.1%
20% MH	21.4%

TABLE 5.12

OPTIMAL SHARE RATES BY PROJECT TYPE

PROJECT TYPE

	100	200	300	400	500	600	700	800	Total
FPI (5% MH)									
IFB	68.3	64.0	68.7	59.4	43.2	66.2	63.1	75.2	66.5
8(d)	75.1	73.9	85.3	76.9	84.4	67.3	66.9	86.4	75.7
Total	73.4	71.9	76.3	69.6	64.7	67.1	65.8	83.3	73.1
FPI (10% MH)									
IFB	36.2	34.7	34.1	26.7	20.0	33.7	29.0	44.9	34.9
8(d)	41.0	39.8	43.7	46.2	48.6	34.4	33.3	50.5	41.3
Total	39.7	38.8	38.5	38.1	34.9	34.2	32.0	48.9	39.5
FPI (15% MH)									
IFB	26.7	24.7	22.1	18.1	16.1	22.5	20.1	34.5	25.2
8(d)	28.9	28.5	28.5	30.7	37.0	23.3	24.5	36.5	30.7
Total	28.3	27.7	25.0	25.5	27.0	23.1	23.3	35.9	29.1
FPI (20% MH)									
IFB	21.1	18.5	16.1	13.2	13.1	16.8	14.7	23.7	19.2
8(d)	21.6	21.8	20.8	22.4	34.6	17.4	17.3	28.5	22.2
Total	21.5	21.1	18.2	18.6	24.3	17.3	16.6	27.1	21.4

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

lower cost firms to reduce their bids to maintain their edge over the high cost firms. Under a 5 percent moral hazard rate, the optimal share rate for this project type is a very high 86.4 percent under an 8(d) award. This project type also has the highest level of share rates over 90 percent compared to other project types.

The utilities and energy, research and development, and medical facilities have the highest optimal share rates compared to other project types under 8(d) awards. The share rates approach a mean value of 85 percent. These projects tend to involve more complex construction and relatively higher technical specifications or requirements than other projects. 8(d) contract awards for the medical and the utilities and energy projects have the highest and second highest differences in bids (as shown in the coefficient of variation, 14.73 and 13.48 percent respectively). On the other hand, the medical facilities projects awarded under an IFB award had an optimal share rate of only 43.2 percent, partly because the IFB medical awards had the lowest coefficient of variation (5.65 percent) of all project types (IFB or 8(d)). Conversely, IFB awards for research and development and the utilities and energy projects had above average mean optimal share rates (these projects had relatively high coefficients of variation). In summary, as the range of expected costs rises, the Air Force needs to offer a higher optimal share rate; as the range narrows, the optimal share rate should be reduced.

Table 5.13 provides details on how the savings rates between the FPI and FFP contract changes as the optimal share rate increases. Under all moral hazard assumptions, the savings rates rise as share rates increase. These observations are consistent with the idea that reducing cost shares makes a contract look more like an FFP contract.

See Tables 5.13 through 5.16 for savings rates based on the number of bidders, optimal share rates, and moral hazard rate. As the optimal share rates rise, savings rates rise. Relative savings rates fall as moral hazard rates rise.

5.3 SIMULATION RESULTS WITH RISK AVERSE FIRMS

In this section, I assume all firms have constant absolute risk aversion, with

TABLE 5.13

FIXED PRICE INCENTIVE SAVINGS RATES (5 PERCENT MORAL HAZARD)

	Bid ≤ 5	5 < Bid ≤ 10	10 < Bid ≤ 15	15 < Bid ≤ 20	Bid > 20
$\alpha \leq .2$					
IFB	5.0	n/a	4.1	4.3	3.7
8(d)	5.4	3.8	3.6	3.8	n/a
$.2 < \alpha \leq .4$					
IFB	5.6	4.7	4.7	4.8	4.5
8(d)	5.6	4.8	4.5	4.4	3.9
$.4 < \alpha \leq .6$					
IFB	6.6	5.4	5.5	5.3	4.9
8(d)	6.8	5.3	5.4	5.5	n/a
$.6 < \alpha \leq .8$					
IFB	7.1	6.4	6.7	n/a	n/a
8(d)	7.2	6.9	6.9	6.9	12.1
$\alpha > .8$					
IFB	14.9	12.6	12.4	12.4	n/a
8(d)	15.0	14.5	13.7	11.2	n/a

TABLE 5.14

FIXED PRICE INCENTIVE SAVINGS RATES (10 PERCENT MORAL HAZARD)

	Bid ≤ 5	5 < Bid ≤ 10	10 < Bid ≤ 15	15 < Bid ≤ 20	Bid > 20
$\alpha \leq .2$					
IFB	2.7	3.2	3.3	3.3	3.4
8(d)	2.3	3.1	2.7	2.9	3.2
$.2 < \alpha \leq .4$					
IFB	2.5	3.4	3.4	3.4	3.3
8(d)	2.5	3.3	3.3	3.6	n/a
$.4 < \alpha \leq .6$					
IFB	6.1	5.0	5.5	6.6	n/a
8(d)	3.8	5.2	5.9	6.8	4.7
$.6 < \alpha \leq .8$					
IFB	8.3	5.5	6.4	n/a	n/a
8(d)	8.4	5.0	6.5	n/a	n/a
$\alpha > .8$					
IFB	11.8	12.1	13.1	n/a	n/a
8(d)	14.1	15.2	14.9	n/a	n/a

TABLE 5.15

FIXED PRICE INCENTIVE SAVINGS RATES (15 PERCENT MORAL HAZARD)

	Bid ≤ 5	5 < Bid ≤ 10	10 < Bid ≤ 15	15 < Bid ≤ 20	Bid > 20
$\alpha \leq .2$					
IFB	1.9	2.5	2.7	2.4	2.1
8(d)	2.1	2.5	2.8	2.9	2.8
$.2 < \alpha \leq .4$					
IFB	2.1	2.7	2.8	2.9	n/a
8(d)	2.4	2.9	2.9	3.1	3.4
$.4 < \alpha \leq .6$					
IFB	5.2	4.9	5.1	n/a	n/a
8(d)	5.3	5.2	5.7	n/a	n/a
$.6 < \alpha \leq .8$					
IFB	6.2	6.5	n/a	n/a	n/a
8(d)	6.9	7.1	n/a	n/a	n/a
$\alpha > .8$					
IFB	9.7	9.5	n/a	n/a	n/a
8(d)	12.1	12.6	n/a	n/a	n/a

TABLE 5.16

FIXED PRICE INCENTIVE SAVINGS RATES (20 PERCENT MORAL HAZARD)

	Bid ≤ 5	5 < Bid ≤ 10	10 < Bid ≤ 15	15 < Bid ≤ 20	Bid > 20
$\alpha \le .2$					
IFB	1.4	1.5	1.6	1.7	1.7
8(d)	1.4	1.7	1.7	2.0	2.4
$.2 < \alpha \le .4$					
IFB	2.0	2.3	2.1	2.2	n/a
8(d)	2.1	2.0	2.1	2.1	n/a
$.4 < \alpha \le .6$					
IFB	4.3	4.4	n/a	n/a	n/a
8(d)	3.9	3.0	3.1	n/a	n/a
$.6 < \alpha \le .8$					
IFB	5.6	5.6	n/a	n/a	n/a
8(d)	5.7	6.3	n/a	n/a	n/a
$\alpha > .8$					
IFB	10.3	n/a	n/a	n/a	n/a
8(d)	12.5	n/a	n/a	n/a	n/a

the coefficient of risk aversion derived in Chapter IV (λ = 8.221 x 10^{-7}). Like the preceding analysis, this section concentrates on the savings and share rates based on project type, contract award, and geographic region.

5.3.1 WEIGHTED SAVINGS RATES

The weighted savings rates were higher under an assumption that firms are risk averse. The change from a risk neutral to a risk averse assumption increased savings by 0.2 percent from present savings under a 5 percent moral hazard rate. See Table 5.17 for the savings data. The increased savings rates do not seem to alter the previous results that incentive contracts are valuable; savings rates still range from 6.5 to 10.8 percent. See Table 5.18 for savings rates by project type. The medical and the utilities and energy projects under the 8(d) awards have the highest savings.

Note that savings rates are higher in all project and contract award types than in the risk neutral cases. Firms build a risk premium into their bids that rises with the riskiness of the contract. The current FFP contract places maximum risk upon contractors, and firms include the maximum risk premium in their bids because of it. An FPI contract allows the Air Force to share some of the risk with the contractor, and to capture a portion of the decrease in the risk premium, as reflected in the projected savings.

These increased savings are due to the risk sharing effect. The risk sharing effect depends not only on λ, but also the difference between c_h and c_1. The standard deviation between c_h and c_1 may not be large enough, in these cases, to make the risk sharing effect reduce τ greatly. Perhaps projects that involve great uncertainty over production costs (e.g., computer equipment) may have greater risk sharing effects and greater savings rates than military construction projects. Several interviewed IFB and 8(d) military construction bidders said that they do not consider the risk of cost overrun large for most contracts. Therefore, they do not greatly increase their bids to compensate for risk aversion.

5.3.2 SAVINGS AND GEOGRAPHIC REGIONS

The savings rates also differ by geographical region. See Table 5.19 for a

compilation for weighted savings by geographical region. All geographical regions reflect higher savings rates with risk aversion.

5.3.3 OPTIMAL SHARE RATES

I now examine how much optimal α values differ if firms are assumed to be risk averse. See Table 5.20 for these optimal α values. The optimal share rates increase from an average share rate of 74.5 percent to 77.8 under a 5 percent moral hazard assumption due to adding the risk sharing effect to the simulation. The optimal share rates are higher in all projects. The average of the IFB and 8(d) projects have much higher optimal share rates in these categories than other project types. The medical and the utilities and energy projects under the 8(d) contract awards have higher mean optimal share rates than the average 8(d) optimal share rates.

The increase in the mean optimal α rates seems slight. Perhaps the variance of expected costs for these contracts is relatively small and this results in this modest rise.

Another interesting observation is that the change in the other projects' optimal share rates appear minor relative to the risk neutral cases (for this λ and for these expected cost variances), only 4 percent. Conversely, the medical and the utilities and energy projects' share rates increase by over 8 percent. In summary, risk aversion is not important to the central conclusions of this dissertation. Savings rates and optimal share rates change little compared to the risk neutral case.

5.4 SUMMARY

The simulations revealed that the Air Force can save money by applying the FPI contract to military construction contracts. The Air Force can reduce its contract payments on military construction projects based on project types, contract award types, and throughout all geographical regions in the United States. Savings did not significantly differ across geographical regions. This

means contracting officers can use a uniform and universal application of FPI contracts throughout the United States.

The simulation results underscore the premises in the McAfee and McMillan model. Savings rates and the optimal share rates fall as the number of bidders rises (as shown in the IFB awards compared to 8(d) awards). Conversely, as moral hazard rates increase, savings rates and the optimal share rates decrease. Finally, if firms are risk averse the savings rates will rise modestly.

The savings rates in this chapter were all positive, but if the Air Force incurs any costs to implement the FPI contract, this cost could conceivably result in net negative savings. The director of the Air Force's Contract Pricing and Contract Administration Division thought there was little or no cost increase to calculate α values, administer, or monitor an FPI contract compared to an FFP contract. Thus, costs for contract administration are believed to be negligible (well below 1 percent). However, several DCAA auditors thought an extra 2 percent cost was appropriate as a maximum expense to auditing costs for FPI contracts.[2] Nevertheless, for the vast majority of projects, even with an additional 2 percent auditing cost, savings are still substantial. At relatively high moral hazard rates, some project types may not have much savings if savings are reduced by the 2 percent audit cost. For example, the medical facilities, under IFB contract award, have a savings rate of only 1.1 percent savings under a 20 percent moral hazard rate.

[2]Interviews with the Defense Contract Audit Agency, 17 July 1991.

TABLE 5.17

WEIGHTED MEAN SAVINGS BETWEEN FFP AND FPI CONTRACTS
UNDER A RISK AVERSE ASSUMPTION

MORAL HAZARD RATE	PERCENT MEAN SAVINGS
5%	10.8%
10%	8.4%
15%	7.3%
20%	6.4%

TABLE 5.18

WEIGHTED SAVINGS RATES BY PROJECT TYPE
UNDER A RISK AVERSE ASSUMPTION

PROJECT TYPE

	100	200	300	400	500	600	700	800
FPI (5% MH)								
IFB	9.5	9.4	8.8	7.7	7.9	8.8	8.1	14.4
8(d)	10.5	10.4	10.3	11.7	12.7	8.1	9.1	15.0
Total	10.2	10.2	9.5	10.1	10.4	8.3	8.8	14.8
FPI (10% MH)								
IFB	8.1	7.9	7.7	5.9	5.8	7.0	6.3	11.3
8(d)	9.2	8.7	10.2	9.8	12.2	6.5	7.0	14.7
Total	8.9	8.4	9.4	7.2	9.3	6.7	6.8	14.1
FPI (15% MH)								
IFB	6.8	6.6	6.3	4.6	4.3	6.7	5.5	11.1
8(d)	8.4	8.1	9.8	9.2	10.9	5.5	6.1	12.5
Total	8.1	7.6	8.3	6.9	7.8	5.7	5.9	12.2
FPI (20% MH)								
IFB	5.6	5.5	5.7	3.9	3.2	6.1	5.0	10.2
8(d)	8.0	7.7	9.1	8.4	9.7	5.0	5.8	12.3
Total	7.4	7.2	7.6	6.2	5.3	5.3	5.4	11.8

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

TABLE 5.19

WEIGHTED SAVINGS BY GEOGRAPHIC REGION
UNDER A RISK AVERSE ASSUMPTION

INCENTIVE CONTRACT

REGION	5% MH	10% MH	15% MH	20% MH
New England	11.1	7.4	7.0	5.9
Middle Atlantic	10.8	7.3	5.7	5.4
South Atlantic	10.9	7.4	6.2	5.7
East North Central	10.3	7.3	6.0	5.5
East South Central	10.3	7.3	6.0	5.5
West North Central	10.6	7.4	6.1	5.6
West South Central	10.8	7.4	6.2	5.7
Mountain	10.1	7.0	5.7	4.9
Pacific	9.8	6.6	5.8	4.6

TABLE 5.20

OPTIMAL SHARE RATES BY PROJECT TYPE UNDER A RISK AVERSE ASSUMPTION

PROJECT TYPE

	100	200	300	400	500	600	700	800	Total
FPI (5% MH)									
IFB	72.9	67.2	74.2	62.0	48.8	70.8	67.3	84.7	71.6
8(d)	78.3	77.5	87.6	79.1	92.1	72.7	70.8	92.3	80.1
Total	76.9	75.4	80.3	72.0	71.3	72.3	69.6	90.2	77.8
FPI (10% MH)									
IFB	38.4	34.8	34.3	26.8	26.6	37.8	29.3	48.7	36.5
8(d)	42.4	41.2	47.3	46.5	57.1	36.4	34.2	58.2	43.9
Total	41.3	40.0	40.3	38.3	42.5	36.6	32.8	55.6	41.9
FPI (15% MH)									
IFB	28.6	24.9	22.3	18.2	20.2	24.6	20.3	39.6	26.7
8(d)	30.2	29.4	32.1	31.0	45.5	24.8	24.6	42.5	31.5
Total	29.8	28.6	26.8	25.7	33.4	24.8	23.6	41.7	30.1
FPI (20% MH)									
IFB	23.8	18.7	16.3	13.3	13.4	17.9	14.8	28.9	20.3
8(d)	22.9	22.4	24.3	22.7	34.9	18.7	18.1	34.8	24.1
Total	23.1	21.6	20.0	18.8	24.6	18.5	17.2	33.1	23.1

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

VI. IMPLEMENTATION OF THE INCENTIVE CONTRACT

The Air Force should use FPI contracts in its military construction program. This contract type can result in lower payments for facility projects. This chapter deals with the issue of how to apply the FPI contract to the military construction program. First, I select an implementation scheme to award the FPI contract. Second, I identify the various actors who are affected by a change to FPI contract use. Third, I examine some actions the Air Force can take to help ease the implementation of FPI contracts. Fourth, I investigate different implications that may result from the use of FPI contracts.

6.1 SELECTING AN FPI CONTRACT AWARD METHOD

In Chapter V, I showed that the use of FPI contracts can save money on military construction projects. In this section, I examine how the Air Force can incorporate the use of FPI contracts in its military construction program. First, I describe various methods to award the FPI contract. Second, I compare the various contract award methods. Third, I propose a method that the DoD can use to apply FPI contracts to the Air Force military construction program.

6.1.1. IMPLEMENTATION METHODS.

In this section, I describe the current FFP contract award method, and then compare it to various FPI contract award methods. The various methods in this section differ by their calculation of the α value. I purposely develop FPI contract options that minimize changes to regulations, education and training, and cost accounting systems discussed later. This will make any selected option easier to apply to the current contract situation.

6.1.1.1 THE CURRENT FFP CONTRACT AWARD METHOD

Chapter II briefly discussed how the Air Force puts a construction project on contract. I now provide a more detailed description of the major contracting actions undertaken to award a contract. This description traces the contracting officer's steps from the facility design to contract modifications. See Figure 6.1 for an outline of how the contracting officer awards an FFP contract. The contracting officer normally advertises a construction contract after design completion, provides bidding information and contract specifications, gathers bids, and then selects the lowest bidder. The lowest bidder then completes the project and receives a payment equal to the bid, unless the contracting officer authorizes a modification to the contract with a payment change to the firm.

This description of the contract process focuses on the actual construction activities after the civil engineers receive the completed facility design. These designs can come from either the government or private firms. The civil engineers use this design as the basis for detailed contract specifications that the bidders use to bid on the contract. The government contracting officer provides the complete design to the winning bidder. The completion of designs normally takes an architect (government or private firm) from six to twelve months.

The appropriate contracting officer (Air Force, COE, or NAVFAC) meets with civil engineering officials, comptroller, Air Force facility user, logistics, judge advocate general, safety, and other personnel after the completion of the facility design to develop a comprehensive construction contract strategy to complete the project, which includes a decision on the contract type. Assuming the group agrees on using an FFP contract, the contracting officer must develop bidding instructions and contract specifications developed from the designs. This process takes about two months.

FIGURE 6.1

CURRENT FFP CONTRACT AWARD PROCESS

COE, NAVFAC, OR USAF CONTRACTING OFFICER PREPARES BID, REPORTING, AND CONTRACT SPECIFICATIONS. USAF USER REPRESENTATION INVOLVED IN ALL AREAS OF CONTRACTING. (2 MONTHS)

CONTRACTING OFFICER EVALUATES PROJECT BASED ON COSTS. IF PROJECT QUALIFIES FOR A SMALL BUSINESS SET ASIDE, SBA FINDS QUALIFIED FIRMS TO BID. (2 WEEKS)

CONTRACTING OFFICER ADVERTISES THE CONTRACT (IFB). IF NOT, SBA NOTIFIES QUALIFIED BIDDERS. (1 MONTH)

CONTRACTING OFFICER RELEASES BID PACKAGES. REQUESTS BIDDERS TO SUBMIT BIDS (45 DAYS)

CONTRACTING OFFICER PUBLICALLY OPENS BIDS AND SELECTS LOWEST BID. (1 DAY)

WINNING BIDDER COMPLETES PROJECT.

WINNING BIDDER SUBMITS PERIODIC REQUESTS FOR PROGRESS PAYMENTS.

DCAA, UNDER SOME CASES, CAN AUDIT FIRM COSTS.

CONTRACTING OFFICER APPROVES PAYMENT. (MAY TAKE UP TO 1 YEAR)

CONTRACTING OFFICER NEGOTIATES MODIFICATIONS WITH FIRM

The contracting officer uses the estimated cost and technical specifications to determine if the project is a candidate for a small and disadvantaged business set aside. If the contract has an estimated value of $2 million or less, it is a candidate for a small business award. The Air Force, Navy or Army can award the contract by IFB instead of competing the contract through the SBA if no small, disadvantaged business is found qualified to bid. The SBA is the final authority to determine whether the contract is awarded by IFB, 8(d), or 8(a) action. The determination to award the contract to a small and disadvantaged business takes about two weeks.

The contracting officer then advertises the contract work. This is not a solicitation for bids, only a notification of a potential contract award and where a firm can get the actual bidding instructions. If the SBA awards the contract, the SBA selects and qualifies potential bidders. The bid advertisement takes one month.

The contracting officer then releases detailed bidding instructions, contract specifications, and other information to potential bidders starting on a publicized date. Contracting officers normally provide 45 days after the release of bidding instructions for firms to submit a bid.

After the contracting officer receives all bids, he publicly opens the bids and selects the lowest bid on a predetermined date using a first price sealed bid auction. This takes one day. However, the contracting officer can re-compete the contract if the lowest bid is greater than 110 percent of the government cost estimate even if the contract is awarded by IFB or competed among a pool of SBA identified small and disadvantaged firms.

After the contracting officer awards the contract, the winning firm has 75 to 120 days to start work depending on the contract specification.

The firm can request progress payments. The contracting officer normally contacts the on-site government civil engineers to ensure that the firm has completed work appropriate to the progress payment. This provides an indicator for the contracting officer to determine if the firm is overrunning or underrunning the bid. If the contracting officer determines that the firm may overrun its bid, this indicates a potential

for a contract default.[1] The contracting officer may need to find a new firm to complete the project which delays facility occupancy.

After the firm completes the facility, the Air Force (and COE or NAVFAC) civil engineers, user, and quality control officers inspect the facility. If they find problems with the construction caused by the firm, the contracting officer can require the firm to fix the problems before he authorizes final payment to the firm. If the firm disagrees with the contracting officer, it can ask for a hearing with the contracting officer. The firm can appeal the contracting officer's decision to a federal court. An Air Force contracting officer, with 30 years of construction related contracting experience, estimated that the government normally takes up to one year to settle final payments with a firm.[2]

The DCAA can audit the firm's cost if the contracting officer suspects fraud or erroneous cost calculations used for progress payments. The contracting officer also requests the DCAA to audit a firm's use of Air Force furnished equipment.

Throughout the life of the contract, the contracting officer has the ability to change the contract. The contracting officer may need to add a specification, delete a requirement, or make other changes. Normally, the contracting officer directly negotiates these changes with the firm. The civil engineers assess the firm's cost proposals for contract modifications. The contracting officer also could advertise a new contract (IFB or 8(d)) award for the change. According to the COE and NAVFAC, the majority of modifications involves changes that do not affect construction costs.[3]

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1. Interview with several construction contracting officers and civil engineers from the Directorate of Civil Engineering at Los Angeles AFB, 28 Feb 1992.
2. Interview with the contracting management section from the Directorate of Civil Engineering at Los Angeles AFB, CA, 28 Feb 1992.
3. Interview with the Director, Air Force Contract Administration Division, the Corps of Engineer's Director of Contract Management, and the Navy Facility and Engineering Command's Director of Contract Policy, 21 Feb 1992.

6.1.1.2 THE CURRENT FPI CONTRACT AWARD PROCEDURE BASED ON THE FAR.

I use inputs from military construction contracting officers to show how they probably would award an FPI contract under the FAR today. FPI contracts are not used for military construction projects today. The DoD and NASA developed a joint Incentive Contracting Guide that provides such guidance for FPI contracts. Unfortunately, this guide assumes the Air Force awards a contract based on responses from the contracting officer's request for proposals from industry. This entails technical and cost evaluations.[4] The award of a military construction contract does not use these methods. Interviewed contracting officials said that they would slightly modify the procedures in the Incentive Contracting Guide since the contracting officer does not use technical evaluations as a part of military construction contract awards (except in design work).[5]

See Figure 6.2 for a detailed illustration of this method. This hypothetical method follows the current FFP method prior to the contracting officer's release of the bid packages. These bid packages include contract specifications, bid instructions, and a contracting officer determined α. An Air Force contracting official said that the selection of an α value would come from an arbitrary calculation from the individual contracting officer.

The contracting officer requests bidders to submit their bids. The contracting officer then selects the lowest bid and awards that firm the contract. The contracting officer informs the firm that the contract payments will not exceed a price ceiling (normally the budgeted amount for the project approved by the Congress) for the contract. This price ceiling establishes a dollar spending level that the federal government will not exceed. If the firm's costs exceed this price ceiling, it receives no further payment. This makes the contract "fixed" and the

4. See Department of the Air Force 1969(a), AFP 70-1-5 Incentive Contracting Guide, p. 55.
5. Interview with the Director, Air Force Contract Administration Division, the Army's Director of Contract Management, and the Navy's Director of Contract Policy, 21 Feb 1992.

share rate becomes 0 for the government at this point. The firm must pay for all costs above the price ceiling with no sharing of the overrun with the government. The firm then starts construction not later than the official start date indicated in the contract.

The firm can request progress payments like the FFP case during the contract. The firm also must submit justification (i.e., billings) for its payments.

After the firm completes the contract work, it submits all billings to the DCAA. The DCAA audits the billings to ensure the firm properly charges direct costs (labor and materials) and indirect costs (capital depreciation) to the contract. The contracting officer then uses the DCAA audited costs to determine the final payment to the firm.

The contracting officer also considers contract modifications during and after the contract's life like the FFP contract award. The firm or the contracting officer can request a modification of the contract at any time. These modifications can include changes in building specifications, completion dates, and other contract requirements.

6.1.1.3 THE MCAFEE AND MCMILLAN FPI CONTRACT PROCESS

The McAfee and McMillan FPI contract process differs from the current FPI approach. Under the McAfee and McMillan FPI model, the contracting officer knows the number of bidders, the values of c_h and c_l, expected cost distribution, firm risk aversion, and moral hazard rate ex ante. See Figure 6.3. From this information, the contracting officer calculates an optimal α and the expected contract payment. This model was developed to show the superiority of FPI contracts, in certain cases, to FFP or CPFF contracts. The model simulation results do show cost savings, and supports the contention of the authors to recommend the use of incentive contracts by the federal government.[6]

If the contracting officer uses this approach, he can then advertise the contract to the public. The contracting officer also makes bid

6. See McAfee and McMillan 1985(b), Incentives in Government Contracting, p. 5.1.

instructions, contract specifications, and the optimal α available to the firms.

The firm calculates an appropriate bid for the contract. These firms submit a sealed bid that the contracting officer opens in public at the appointed time and place according to the bid instructions. The contracting officer then selects the lowest bid from the pool of bidders and selects the firm with the lowest bid. The contracting officer and successful firm then sign the contract. The firm then starts work on the contract.

After the firm completes the contract, McAfee and McMillan propose that auditors randomly select firms to audit actual costs like the Internal Revenue Service does for income tax returns. Only a few contracts would undergo a detailed cost audit. The DCAA may institute certain tests that may identify potentially fraudulent cost reports. This reduces auditing costs. If the DCAA finds fraud, the federal government should vigorously prosecute the firm. This acts as an example to other firms that if they cheat on cost billings they will get prosecuted. The contracting officer can make the total payment to the firm once it receives the billings and determines a proper payment.

6.1.1.4 PROPOSED FPI CONTRACT AWARD PROCESS USING A SINGLE α FOR EACH PROJECT TYPE

The Air Force can modify its current FPI contract approach fairly easily to accommodate the use of a single α for each project and contract award type. Instead of arbitrarily determining α values, the contracting officers can use the simulation results from the McAfee and McMillan model to determine what optimal share rate, by project type, minimizes payments for contracts in a particular project type. See Figure 6.4 for a diagram of this approach. This approach represents an attempt to maximize savings by using a single optimal α value for an entire project type. The contracting officer then uses this single α value for bid solicitation. See Table 6.1 for a list of sixteen α values (eight project types under IFB and 8(d) awards) that a contracting officer would use.

FIGURE 6.2

THE CURRENT FPI CONTRACT AWARD PROCESS

COE, NAVFAC, OR USAF CONTRACTING OFFICER PREPARES BID, REPORTING, AND CONTRACT SPECIFICATIONS. USAF USER REPRESENTATION INVOLVED IN ALL AREAS OF CONTRACTING. (2 MONTHS)

CONTRACTING OFFICER EVALUATES PROJECT BASED ON COSTS. IF PROJECT QUALIFIES FOR A SMALL BUSINESS SET ASIDE, SBA FINDS QUALIFIED FIRMS TO BID. (2 WEEKS)

CONTRACTING OFFICER ADVERTISES THE CONTRACT (IF IFB). IF NOT, SBA NOTIFIES QUALIFIED BIDDERS. (1 MONTH)

CONTRACTING OFFICER DETERMINES α (ARBITRARILY) (1 WEEK)

CONTRACTING OFFICER RELEASES BID PACKAGES AND α. REQUESTS BIDDERS TO SUBMIT BIDS (45 DAYS).

CONTRACTING OFFICER PUBLICALLY OPENS BIDS AND SELECTS LOW BID(1 DAY)

BIDDER COMPLETES PROJECT.

WINNING BIDDER SUBMITS PERIODIC COST DATA FOR PROGRESS PAYMENTS.

DCAA AUDITS COSTS TO DETERMINE FINAL COSTS. (1 MONTH)

CONTRACTING OFFICER APPROVES PAYMENT. (MAY TAKE UP TO 1 YEAR)

CONTRACTING OFFICER NEGOTIATES WITH FIRM FOR MODIFICATIONS.

FIGURE 6.3

MCAFEE AND MCMILLLAN FPI CONTRACT AWARD PROCESS

CONTRACTING OFFICER KNOWS # OF BIDS, COST DISTRIBUTION, AND h_o EX ANTE.

CONTRACTING OFFICER EVALUATES PROJECT BASED ON ABOVE DATA. CALCULATES ESTIMATED PAYMENT AND α.

CONTRACTING OFFICER RELEASES α, BID INFORMATION, CONTRACT SPECIFICATIONS

BIDDERS BID ON PROJECT

CONTRACTING OFFICER PUBLICALLY OPENS BIDS AND SELECTS LOWEST BID.

BIDDER COMPLETES PROJECT

DCAA RAMDOMLY AUDITS COSTS TO DETERMINE FINAL COSTS.

CONTRACTING OFFICER APPROVES PAYMENT.

NO ESTIMATES OF TIME TO COMPLETE ACTIVITIES AVAILABLE.

FIGURE 6.4

PROPOSED FPI CONTRACT AWARD PROCESS USING SINGLE α FOR EACH PROJECT TYPE

COE, NAVFAC, OR USAF CONTRACTING OFFICER PREPARES BID, REPORTING, AND CONTRACT SPECIFICATIONS. USAF USER REPRESENTATION INVOLVED IN ALL AREAS OF CONTRACTING. (2 MONTHS)

CONTRACTING OFFICER EVALUATES PROJECT BASED ON COSTS. IF PROJECT QUALIFIES FOR A SMALL BUSINESS SET ASIDE, SBA FINDS QUALIFIED FIRMS. (2 WEEKS)

CONTRACTING OFFICER USES SINGLE α THAT MAXIMIZES SAVINGS FOR FACILITY CONTRACTS BY PROJECT TYPE (1 WEEK)

CONTRACTING OFFICER RELEASES BID PACKAGES AND α. REQUESTS BIDDERS TO SUBMIT BID (45 DAYS).

CONTRACTING OFFICER PUBLICALLY OPENS BIDS AND SELECTS LOW BID (1 DAY)

BIDDER COMPLETES PROJECT.

WINNING BIDDER SUBMITS PERIODIC REQUEST FOR PROGRESS PAYMENTS.

DCAA AUDITS COSTS TO DETERMINE FINAL COSTS. (1 MONTH)

CONTRACTING OFFICER APPROVES PAYMENT. (MAY TAKE UP TO 1 YEAR)

CONTRACTING OFFICER NEGOTIATES WITH FIRM FOR MODIFICATIONS.

TABLE 6.1

OPTIMAL SHARE RATES (5% MORAL HAZARD RATE)

	PROJECT TYPE							
	100	200	300	400	500	600	700	800
OPTIMAL α BY PROJECT TYPE								
IFB	69.6	65.2	70.0	60.5	43.9	67.5	64.3	76.7
8(d)	76.5	75.3	86.9	78.3	86.0	68.6	68.2	88.0
MEAN α BY PROJECT TYPE								
IFB	68.3	64.0	68.7	59.4	43.2	66.2	63.1	75.2
8(d)	75.1	73.9	85.3	76.9	84.4	67.3	66.9	86.4

PROJECT TYPE

100 Operational Facilities
200 Maintenance & Logistics Repair Facilities
300 Research & Development Facilities
400 Warehouse & Storage Facilities
500 Medical Facilities
600 Administrative & Computer Facilities
700 Living & Personnel Support Facilities
800 Utilities & Energy Projects

The contracting officer also can modify this approach to include other characteristics. For example, the contracting officers can expand this proposal to use geographic regions. The rest of the proposed process mirrors the current FPI contract method under the FAR.

The contracting officer uses α values from historical data to estimate an optimal contract strategy. The contracting officer does not have to consider expected costs, number of bidders, or other considerations. He only views project types, or other characteristics, as the most important factor for contract strategy to use the appropriate α.

This method is fairly easy to implement since I have already calculated the optimal α values for the military construction program using the McAfee and McMillan model. Additionally, the method includes a rather simple approach of segregating military construction contracts by project type and contract award type.

6.1.1.5 PROPOSED FPI CONTRACT AWARD PROCESS USING THE AVERAGE α FOR EACH PROJECT TYPE

In this approach, the government uses the mean of the individually determined α values, by project type and contract award, from the simulation results. See Figure 6.5 for an outline of the approach. This approach is similar to the above method, but the share rates do not optimize savings by project type. The mean share rate represents an average of individual share rates that optimize their respective projects. The contracting officer uses the mean α value for each project type under each contract award. This allows the contracting officer to use a single α value for each project type depending on whether the contracting officer uses an IFB or 8(d) contract award, rather than individually determining each.

Like the previous method, the contracting officer receives a list of share rates for each project type by IFB and 8(d) contract award. See Table 6.1 for a representation of these values under the two proposals that the contracting officer would receive if the Air Force implements either proposal.

FIGURE 6.5

PROPOSED FPI CONTRACT AWARD PROCESS USING PROJECT TYPE AVERAGE α

CONTRACTING OFFICER PREPARES BID AND CONTRACT SPECIFICATIONS. USAF USER REPRESENTATION INVOLVED IN ALL AREAS OF CONTRACTING. (2 MONTHS)

CONTRACTING OFFICER EVALUATES PROJECT BASED ON COSTS. IF PROJECT QUALIFIES FOR A SMALL BUSINESS SET ASIDE, SBA FINDS QUALIFIED FIRMS. (2 WEEKS)

CONTRACTING OFFICER ADVERTISES THE CONTRACT (IF IFB). IF NOT, SBA NOTIFIES QUALIFIED BIDDERS (1 MONTH)

CONTRACTING OFFICER USES MEAN α RATE BASED ON PROJECT TYPE (1 WEEK)

CONTRACTING OFFICER RELEASES BID PACKAGES AND α. REQUESTS BIDDERS TO SUBMIT BIDS (45 DAYS).

CONTRACTING OFFICER PUBLICALLY OPENS BIDS AND SELECTS LOW BID. (1 DAY)

BIDDER COMPLETES PROJECT

WINNING BIDDER SUBMITS PERIODIC COST DATA FOR PROGRESS PAYMENTS.

DCAA AUDITS COSTS TO DETERMINE FINAL COSTS. (1 MONTH)

CONTRACTING OFFICER APPROVES PAYMENT. (MAY TAKE UP TO 1 YEAR)

CONTRACTING OFFICER NEGOTIATES WITH FIRM FOR MODIFICATIONS.

6.1.1.6 PROPOSED FPI CONTRACT AWARD PROCESS USING INDIVIDUALLY CALCULATED α PROJECTIONS

The contracting officer also can calculate individual α values for each project. See Figure 6.6 for more details. The contracting officer calculates an individual α value for each project. The contracting officer needs to estimate the number of bidders, moral hazard rate, risk aversion, and the range of expected costs (needs estimated c_h and c_l values, I retain the assumption of a uniform expected cost distribution). This proposal is similar to the McAfee and McMillan method, but it relies on estimated information. The contracting officer then calculates the optimal α value and τ based on these estimates.

A contracting officer can estimate the number of bidders. When the contracting officer advertises the potential contract, he can count the number of inquiries about bid information, which provides an estimate of the number of bidders. The advertisement also might request any potential bidders to contact the contracting officer for more details if the award is an IFB award (an 8(d) award allows the SBA contracting officers to set the number of bidders). This allows the contracting officer to determine how many serious bidders might compete for the contract. The contracting officer also could use historical data to establish how many bidders normally bid on particular military construction contracts.

The contracting officer's most difficult task involves estimating c_h and c_l. The Air Force already estimates a single project cost. Perhaps the CCMAS cost model might provide an upper and lower estimate that can act as a basis to estimate c_h and c_l.

The Air Force can create a computer program that allows the contracting officer to calculate the optimal α value. This program could allow the contracting officer to input the number of bidders, c_h, c_l, moral hazard rate, and a risk aversion measure. The computer program can reduce a contracting officer's chance of erroneously calculating α by hand. It also allows the contracting officer to perform a sensitivity analysis by varying values for the number of bidders, costs, moral hazard, and the risk aversion measure.

FIGURE 6.6

PROPOSED FPI CONTRACT AWARD PROCESS USING INDIVIDUALLY CALCULATED α RATES

COE, NAVFAC, OR USAF CONTRACTING OFFICER PREPARES BID, REPORTING, AND CONTRACT SPECIFICATIONS. USAF USER REPRESENTATION INVOLVED IN ALL AREAS OF CONTRACTING. (2 MONTHS)

CONTRACTING OFFICER EVALUATES PROJECT BASED ON COSTS. IF PROJECT QUALIFIES FOR A SMALL BUSINESS SET ASIDE, SBA FINDS QUALIFIED FIRMS. (2 WEEKS)

CONTRACTING OFFICER ADVERTISES THE CONTRACT (IF IFB). IF NOT, SBA NOTIFIES QUALIFIED BIDDERS. (1 MONTH)

CONTRACTING OFFICER GATHERS RELEVANT HISTORICAL DATA. USES ESTIMATED VALUE FOR NUMBER OF BIDDERS, c_h and c_l BASED TO CALCULATE OPTIMAL α. (1 MONTH)

CONTRACTING OFFICER RELEASES BID PACKAGES AND α. REQUESTS BIDDERS TO SUBMIT BIDS (45 DAYS).

CONTRACTING OFFICER PUBLICALLY OPENS BIDS AND SELECTS LOW BID (1DAY)

BIDDER COMPLETES PROJECT

WINNING BIDDER SUBMITS PERIODIC REQUEST FOR PROGRESS PAYMENTS.

DCAA AUDITS COSTS TO DETERMINE FINAL COSTS. (1 MONTH)

CONTRACTING OFFICER APPROVES PAYMENT. (MAY TAKE UP TO 1 YEAR)

CONTRACTING OFFICER NEGOTIATES WITH FIRMS FOR MODIFICATIONS.

FIGURE 6.7

PROPOSED FPI CONTRACT AWARD PROCESS USING A MENU OF CONTRACTS

CONTRACTING OFFICER PREPARES BID AND CONTRACT SPECIFICATIONS. USAF USER REPRESENTATION INVOLVED IN ALL AREAS OF CONTRACTING. (2 MONTHS)

CONTRACTING OFFICER EVALUATES PROJECT BASED ON COSTS. IF PROJECT QUALIFIES FOR A SMALL BUSINESS SET ASIDE, SBA FINDS QUALIFIED FIRMS. (2 WEEKS)

CONTRACTING OFFICER ADVERTISES THE CONTRACT (IF IFB). IF NOT, SBA NOTIFIES QUALIFIED BIDDERS. (1 MONTH)

CONTRACTING OFFICER ESIMATES THE # OF BIDDERS BASED ON INQUIRIES AND HISTORICAL DATA. USES A RANGE FOR c_h and c_l TO CALCULATE α VALUES. (1 MONTH)

CONTRACTING OFFICER RELEASES BID PACKAGES AND MENU OF FPI CONTRACTS. BIDDERS BIDS BASED (45 DAYS)

CONTRACTING OFFICER PUBLICALLY OPENS BIDS AND SELECTS BIDDER BASED ON EXPECTED PAYMENT (1 DAY)

BIDDER COMPLETES PROJECT.

WINNING BIDDER SUBMITS PERIODIC REQUEST FOR PROGRESS PAYMENTS.

DCAA AUDITS COSTS TO DETERMINE FINAL COSTS. (1 MONTH)

CONTRACTING OFFICER APPROVES PAYMENT. (MAY TAKE UP TO 1 YEAR)

CONTRACTING OFFICER NEGOTIATES WITH FIRM FOR MODIFICATIONS.

TABLE 6.2

CRITERIA TO SELECT AN IMPLEMENTATION PLAN

- Level of savings the Air Force realizes under each implementation plan.

- How many and what types of changes are required from the current contracting process to the proposed FPI implementation process.

  -- legal (regulations and law)
  -- procedural
  -- education/training

- Cost to implement proposal.

- Time to implement proposal.

- Effect on private firms.

The remainder of the process is similar to the current FPI contract based on the FAR. The contracting officer uses the individual α instead of the arbitrary α value.

6.1.1.7 PROPOSED FPI CONTRACT AWARD PROCESS USING A MENU OF CONTRACTS

A contracting officer also might calculate several potential α values to use on the project and allow a bidder to bid based on his selected α from the contract menu. See Figure 6.7 for an outline of this proposal. This proposal allows the bidder some freedom of selection.

The government requires additional work to find the best array of α values that optimize its payments. The contracting officer can estimate values for c_l, c_h, the number of bidders, moral hazard and risk aversion. A contracting officer might use this information to calculate the optimal α and expected contract payments, if additional theory were worked out.

The bidder with the lowest expected payment wins the award. The contracting officer can calculate the expected payment using equation (52) in Chapter IV, and the additional theory that must be developed. The contracting officer must use the estimated costs, number of bidders bidding on the specific option, the α for the option, and the moral hazard rate. The contracting officer uses the minimum and maximum bids to re-calculate c_h and c_l by using equation (51) in Chapter IV. The contracting officer needs at least two firms to estimate these values, otherwise he must use the pre-bid government cost estimates. It could turn out to be, of course, that the optimal menu of α's is in fact a single α.

The contracting officer authorizes progress payments, requests cost audits, and negotiates modifications like the previous methods.

6.1.2 AN EVALUATION OF FPI IMPLEMENTATION APPROACHES

In this section, I discuss the advantages and disadvantages of each contract implementation proposal in order to apply the FPI contract for the military construction program. I use the criteria in Table 6.2 to compare each alternative. I then subjectively rank the implementation

contract award methods based on their relative standings using the criteria in Table 6.2. I then select the best method to award the FPI contract for the Air Force's military construction program.

6.1.2.1. THE CURRENT FFP CONTRACT AWARD METHOD

This option requires no changes to the present military construction contracting activities. The federal government has documented the FFP contract award process in the FAR and it has extensively used this contract throughout the federal government. The federal government does not need to change any regulations, policies, procedures, training programs, or contracting directives if the Air Force decides to continue the use of FFP contracts. Additionally, the Air Force does not incur additional costs (other than the lost opportunity cost of the savings from using FPI contracts) or time to implement the program. The contracting officer does not have to calculate an optimal α value and the DCAA does not need to conduct extensive cost auditing. Private firms and the AGC would like this option; they support the continued use of the FFP contract (although, perhaps they underestimate the benefits of risk sharing). Many interviewed contracting officers also prefer this option since they do not have to learn a new contracting technique. However, they did say that they would accept and apply the FPI contract in military construction if the Air Force changed contracting policies.

Without changed policies, the Air Force will forego the possible savings from using FPI contracts. As the preceding chapters have shown, the Air Force should implement the FPI contract due to its level of savings. The savings of up to 10.6 percent in the military construction program seems too lucrative to bypass.

6.1.2.2 THE CURRENT FPI CONTRACT AWARD PROCEDURE BASED ON THE FAR.

This method uses an FPI contract, however, one does not know how much the Air Force will save relative to the FFP contract. Since the contracting officers arbitrarily select a project α value, the savings

rates are probably less than the results from the McAfee and McMillan model, and could be negative, if the α chosen leads to worse results than $\alpha = 0$, the FFP level.

The current FPI contract award process has several advantages. This approach follows the present FAR and service contracting procedures. Therefore, the government does not need to change many policies, regulations, or laws. Contracting officers within the DoD (but not military construction contracting officers) are familiar with the procedure and may feel more comfortable with this process. The military construction contracting officers could ask for advice from contracting officers that use FPI contracts to implement this proposal. The contracting officers also may need refresher classes to ensure they are familiar with the FPI contract.

This process, in the opinion of these contracting officers, follows the general FAR guidelines for the FPI contracts. These contracting officers did admit that they probably would have to draft some instructions to base level contracting officers to implement this contract. They do think base level contracting officers can apply this FPI contract method to military construction projects.

This proposal would take one of the shortest time periods relative to the other proposals to implement in the federal government. This contract award method follows the current FAR with little modification.

Unfortunately, this contract approach has some drawbacks. The biggest problem involves the selection of the share rate. The contracting officer calculates α based on an arbitrary decision. Contracting officials frequently mentioned that they had witnessed contracting officers awarding FPI contracts on weapon systems using an arbitrary share rate based on historical precedent. The selected α will result in a less than optimal payment for the Air Force.

This method also entails some additional expense. The major cost to implement this proposal involves the use of the DCAA to audit all FPI contract costs. The Air Force also might incur some delay in applying the FPI contract as the contracting officers improve their ability to award FPI contracts. This delay may affect other contracting activities as the

contracting officers concentrate on learning about the FPI contracts. However, this is a one time start-up cost.

If firms are risk neutral, they would oppose the use of FPI contracts since it reduces their profits. See Appendix 6.1 for a more detailed discussion.

6.1.2.3. THE MCAFEE AND MCMILLAN FPI CONTRACT PROCESS

The assumptions behind the formal McAfee and McMillan model are at variance with reality, therefore it cannot be precisely implemented as it stands.

There are several disadvantages to using this model approach as a practical option. See Table 6.3 for a list of how the McAfee and McMillan model differs from reality and the current FAR procedures. Although the McAfee and McMillan model can calculate an optimal α, this model assumes that a contracting officer knows much detailed information about the bidders and their bids ex ante. This assumption is unrealistic since contracting officers cannot know all these parameters for a practical application of this model. I use the model results only to determine if the Air Force should use FPI contracts in its military construction program (I use ex post data for the calculations). The actual application and administration of the FPI contracts involve further considerations.

The contracting officer also cannot use the McAfee and McMillan model in its present form unless he applies it in conjunction with certain contracting actions found in the FAR. In addition, McAfee and McMillan make no mention about certain contracting actions. The model does not consider warranties (that affect payments in the current system), small business set asides, contract modifications, and progress payments. For example, the McAfee and McMillan model assumes the firm builds the project and collects the final payment after project completion. The contracting officer normally makes final payments to the firm when all discrepancies concerning the facility are settled (e.g., facility meets contract specifications). The Air Force would require a waiver from the FAR by the

TABLE 6.3

HOW MCAFEE AND MCMILLAN DIFFER FROM CONTRACTING REALITY

- All information known ex ante.

- No provision for price ceilings.

- No provision for contract modifications.

- All contracts awarded IFB. No provision for 8(d) awards.

- McAfee and McMillan use random cost audits for FPI contracts.

- Payments, under McAfee and McMillan, are made immediately after completion of construction. Under the FAR, the government normally requires a warranty for construction work and ties payment to the end of the warranty period.

- Progress payments not considered.

Congress to eliminate this requirement.

6.1.2.4 PROPOSED FPI CONTRACT AWARD PROCESS USING A SINGLE α FOR EACH PROJECT TYPE

This proposal has a slightly lower calculated savings rate than that calculated under the McAfee and McMillan model approach assuming it could be precisely applied. These savings fall from 10.6 percent to 10.1 percent. These payment reductions still offer the government significant savings. This proposed FPI contract award process includes similar contracting actions to the current FPI approach described in Section 6.1.2.2. These two FPI contract proposals take similar approaches to reduce implementation problems.

Since some contracting officers use historical precedent for their selection of α, they should not oppose the use of α values calculated from this historical military construction data like this proposal.

The major disadvantage of this method involves the use of a single α value for an entire project type. The optimal α for an individual project may be quite different from the simple value that optimizes over the project type. The contracting officer only has eight project types to choose an α and two contract award types. The use of an average α value may lead to some loss in optimality in regard to savings for individual projects.

6.1.2.5 PROPOSED FPI CONTRACT AWARD PROCESS USING THE AVERAGE α FOR EACH PROJECT TYPE

This proposal is very similar to the proposal that uses the single α that minimizes the Air Force's payments by project type. The only difference involves the contracting officer's calculation of the α value. The contracting officer uses the average of the individually calculated α values from the simulation in this proposal. Of course, the use of the average value will not optimize the savings for the project type. Even though the α values in this proposal do provide savings to the government, they should in general, not produce as high a rate of savings as the

individually determined α value proposals (the savings average about 9.7 percent).

6.1.2.6. PROPOSED FPI CONTRACT AWARD PROCESS USING INDIVIDUALLY CALCULATED α PROJECTIONS.

This approach involves contracting officers calculating individual α values for each project (like the McAfee and McMillan model). Instead of using an arbitrary, historical, or average α value, the contracting officer collects data and estimates an optimal α. This allows a contracting officer to tailor an α value for a particular contract situation based on his assumptions regarding expected costs, number of bidders, moral hazard, or risk aversion measure.

The contracting officer also has the option to calculate various α values by merely inputting different parameter values into the computer program. This allows him to conduct sensitivity analyses and adjust his estimates.

This approach applies the spirit of the McAfee and McMillan model to the FAR procedures using current contracting procedures. This can reduce the cost and time to implement the proposal. Additionally, the Air Force minimizes many changes to the contracting system in implementing this proposal. This proposal does incur an additional cost of developing the appropriate software and computer systems to allow contracting officers to estimate the α value. The software should not involve a very large initial or operating expense.[7]

A problem with this approach includes the use of contracting officer assumptions involving the expected cost range and number of bidders. The estimate of the range between expected costs is crucial to the computed optimal α value. If the Air Force can develop a reasonable estimate of these costs, the problem becomes easier.

7. Interview with the Director, Air Force Contract Administration Division, 11 Mar 1992.

6.1.2.7. PROPOSED FPI CONTRACT AWARD PROCESS USING A MENU OF CONTRACTS

This proposed method has many characteristics like the current FPI contract award method in Section 6.1.2.2. The contracting officer needs to calculate appropriate α values. However, the Air Force needs to modify the FAR to allow it to offer a menu of contract options. Regulations should include how the contracting officer selects α values and how he will choose the bid that minimizes the government's expected contract payment (selects the lowest bidder). This may entail much time to study the legal, contracting, and cost ramifications of this option.

Under this proposal, savings could equal the theoretical McAfee and McMillan contract award method. Unless the contracting officer carefully selects α values, the Air Force may have lower relative savings. The contracting officer could select an optimal α equal to the theoretical McAfee and McMillan contract award method. The firms should bid the same amount for the contract as under the McAfee and McMillan award. However, this approach is impractical.

This approach creates many problems for the contracting officer. If a contracting officer uses this approach, he must determine how many different contract options he will use. Too many options may confuse both the contracting officer and the firm. Additionally, the contracting officer must determine what α values to use. The contracting officer may offer options that may not minimize government payments. Finally, the contracting officer may face more contract protests concerning awards from using this method. The losing bidders may protest the assumptions used by the contracting officer to determine the award winner based on the firms' expected payments. This may increase litigation between the federal government and bidders.

6.1.3 SELECTING AN IMPLEMENTATION METHOD

In this section, I compare the various implementation proposals. I use a rating scheme to compare these proposals. I then provide some observations about the ratings.

The comparisons use the criteria in Table 6.2 to select the best method to apply the FPI contract. I subjectively rank these criteria from the most to least important to the Air Force. For example, I consider savings as the most important criterion in the study and the effect on private firms as the least important. I rank these criteria in the following order: savings to the Air Force, the number of required contracting changes to implement the proposal, time to implement, cost to implement, and effect on private firms.

Once I rank the criteria, I rate each proposal relative to other proposals by using a numeric scale from 1 (the best) to 7 (the worst). See Table 6.4 for these ratings. I include the current FFP contract method to provide a benchmark for comparison.

Notice that in savings, the McAfee and McMillan approach, the individually determined α, and the Menu of Contracts (assuming the contracting officer offers an optimal α) provide the best levels of savings. Thus, one should start focusing on these approaches since the level of savings is very important to the Air Force.

Contracting changes also affect the decision to select an FPI contract award method. The current FPI contract method, FPI contract use of a single optimal α for each project type, and the use of the mean α of individually calculated share rates under each project type require few changes relative to the FFP contract method. The McAfee and McMillan approach requires the most changes of all proposals.

The Air Force does not need much time to implement many of these FPI contract proposals. Some of the proposals require just a few modifications to policy letters or minor changes to regulations (compared to the McAfee and McMillan approach). The calculation of α values can range from the single use of a mean value to an individually determined α value. The individually calculated optimal α value proposal requires the development of software to calculate α, which should not take long to develop as discussed earlier.

Costs to implement various proposals also differ. The additional costs to implement the proposals are relatively small compared to the

TABLE 6.4

CRITERIA (Ranked)	OPTIONS						
	1	2	3	4	5	6	7
Savings.	7	6	1	4	5	1	1
Changes required.	1	2	7	2	2	5	6
Time to implement.	1	2	7	3	3	3	6
Costs to implement.	1	3	2	3	3	6	7
Acceptance by private firms.	1	3	7	3	3	3	2

OPTIONS:

1 - Current FFP Contract Award Method

2 - Hypothetical FPI Award Procedures

3 - McAfee and McMillan FPI Contract Process

4 - Proposed FPI Contract Award Process Using A Single α For Each Project Type

5 - Proposed FPI Contract Award Process Using The Average α For Each Project Type

6 - Proposed FPI Contract Award Process Using Individually Calculated α Projections

7 - Proposed FPI Contract Award Process Using A Menu Of Contracts

savings from using FPI contracts. As discussed above, the largest cost of implementing the FPI contract is the DCAA auditing cost. The McAfee and McMillan approach uses a random audit while the other methods use complete DCAA audits. This results in a lower cost than the other FPI contract methods. The menu of contracts proposal requires additional contracting administration to evaluate which options to offer and how to select the winning bidder.

Finally, the government must consider the degree of acceptance of each proposal by private firms. Although the attitudes of private firms are important, the goal of increasing savings is paramount. In general, the private firms would oppose the use of FPI contracts. But if the Air Force offers firms an FPI contract scheme, the firms I interviewed believe the menu of contracts approach would be best. However, they would consider all FPI contract options.[8] These firms believe the McAfee and McMillan approach deviated too much from the FAR and the government would have a problem implementing this option.

6.1.4 A RECOMMENDATION FOR AN FPI CONTRACT PROPOSAL

If the Air Force wants to implement an FPI contract proposal, it should select a method that maximizes savings while minimizing changes to regulations, costs, time to implement and other adverse effects. Some proposals do better in one category, while performing worse in others. The proposals involving the McAfee and McMillan approach and individually calculating α values score the highest in savings (however, the McAfee and McMillan method has a higher net savings rate due to lower auditing costs). However, the proposal that involves individually calculated α outperforms or meets the McAfee and McMillan approach in four of the remaining five criteria. Even the option of using a single α for each project type (that which maximizes savings across the type) outperforms the McAfee and McMillan approach in two categories.

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8. Interview with 23 construction firms (13 IFB firms and 10 8(d) firms) from 4-6 Nov 1990.

I suggest that the Air Force use two methods sequentially to apply the FPI contract. The Air Force should first use the proposal involving a single α value (that which maximizes savings per project type) in the short term. It should then use the proposal of individually calculated α values in the long term. Both methods provide a relatively high rate of savings, and they score well on the other criteria given above.

These proposals give the Air Force many options. The contracting officers will need time to adjust to the use of FPI contracts. The use of the single α value per project type uses an α value based on historical data and analyses, unlike the arbitrary selection of α. This eases the selection of α values for the contracting officer and allows him to get familiar with the FPI contract without having to calculate an α value. This also provides some time for the Air Force to develop software and procedures for the contracting officer to estimate the optimal α by individual project. As soon as the Air Force can successfully adopt the use of individually developed α values, it can drop the use of the single α value per project type method.

The Air Force can increase the use of computer programs like the CCMAS and PDC to implement the proposals. The Air Force continually upgrades its CCMAS computer program to improve estimated military construction project costs. Perhaps, the Air Force can use this cost estimation model to provide the necessary range of estimates to calculate the optimal α value. The PDC system also contains much historical data that the contracting officer can use to estimate the number of bidders per project and other characteristics. If the contracting officer cannot estimate bidders per project by the number of inquiries about the contract, he could use this historical data. A computer programmer might bridge the use of the CCMAS, PDC, and contracting officer supplied data to allow one to calculate an optimal α value and an expected payment. The computer program allows contracting officers to conduct sensitivity analyses.

6.2 ACTORS IN MILITARY CONSTRUCTION CONTRACTING

Various actors within the federal government and private industry will have to change their behavior to accommodate the implementation of the FPI contract in the military construction program. This section describes these actors and their potential reactions to this change in contracting.

6.2.1 GOVERNMENT ACTORS

Increased use of incentive contracts by the Air Force directly affects contracting officers, comptrollers, judge advocate generals, and civil engineers. These changes also affect the Army and Navy.

6.2.1.1 CONTRACTING OFFICERS

The actors most affected by increased FPI contract use are government contracting officers. Contracting officers at the base level must implement these changes and their workloads will increase. The introduction of FPI contracts may severely affect their ability to award contracts and alter certain roles and responsibilities of the contracting officer.

Contracting officers may not feel adequately prepared to award FPI contracts due to their complex nature relative to FFP contracts. Today's contracting officers suffer from a lack of contracting experience. This lack of experience is due to the retirement of many senior civil servant contracting officers who entered federal government service in the 1950s and 1960s; departure of contracting officers from government service due to low pay relative to their private industry counterparts; and the drawdown of military and civil servant personnel.[9] Although a younger, less experienced contracting officer force may have less resistance to the idea of using incentive contracts, this also creates some problems. A

9. Interview with the Director, Air Force Contract Administration Division, 21 Jun 1990.

1986 American Bar Association survey of contracting officers found that "they lacked confidence in the value of their training" to prepare them to operate in complex, rapidly changing contracting situations.[10] Since the implementation of FPI contracts entails more contract administration than FFP contracts, these contracting officers may feel that they lack adequate training and experience to award an FPI contract.

Contracting officers must orchestrate all phases of contracting activities, but they usually specialize in one of two areas: procuring activities or contract administration (this applies to all services). The procuring contracting officer (PCO) negotiates, signs, terminates, and settles disputes between the government and the private firm. The administrative contracting officer (ACO) normally handles payments, modifications, and monitors contract performance. The government assigns most ACOs to the Defense Contract Management Agency to monitor large production contracts (e.g., aircraft or ship contracts), but base level ACOs normally handle contract administrative tasks (e.g., ensure contract status reports are completed and make progress payments) for military construction projects (or ACOs assigned from a regional COE or NAVFAC contracting activity). The PCOs would determine an optimal share rate, award the contract, negotiate any contract disputes or modifications, and terminate the contract. These activities would complicate what most contracting officers consider a somewhat "easy" award of a military construction contract using an FFP contract.

If the Air Force uses FPI contracts for military construction, an ACO would have to oversee more contract details. The ACOs would need to monitor any potential project cost overrun or underrun by working more intensely with price analysts, auditors, civil engineers, quality assurance representatives, property administrators, and others. This will affect the determination of contract payments to the firm since the ACO might uncover fraudulent activities or mistakes in cost accounting by the firm. This reduces the available time to monitor other contracts and may influence potential promotions.

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10. See Fox, The Defense Management Challenge, p. 165

6.2.1.2 THE DEFENSE CONTRACT AUDIT AGENCY (DCAA)

The DCAA is responsible for providing contract auditing during and after contract performance and contract accounting/financial advice to the PCO and ACO. The DCAA's responsibilities include examining and developing sufficient evidence to verify contractor claimed costs and whether the firm applies these costs properly to the correct contract.[11] The use of FPI contracts will increase the work of the DCAA. This means the DCAA will need more auditors, and require additional resources.

Supporting the DCAA is the Air Force Audit Agency (AFAA). Though the DCAA is the primary organization responsible for contract cost evaluation, the AFAA can conduct the audit activities involving construction contracts if there are no DCAA auditors available.[12] Most Air Force major bases have access to a resident installation level auditor (over 54 audit offices).[13]

6.2.1.3 COMPTROLLER

Another government actor affected by a change to incentive contracts is the comptroller. If the incentive contract can reduce contract payments, this will help the comptroller to meet military construction requirements with limited resources. Incentive contracts, on average, do reduce government expenditures, but the comptrollers must be aware that some individual contracts may face potential cost overruns that could require more funds than planned. The average payments, however, should result in an overall decrease in Air Force expenditures.

Comptrollers face two major problems with incentive contracts. They lack experience at base level to budget for incentive contracts and the Air Force needs to determine how to handle savings from these contracts.

11. See Defense Contract Audit Agency, DCAA Contract Audit Manual, p. 102.
12. Ibid, p. 123.
13. See Air Force Association, "The United States Air Force in Facts and Figures," p. 108.

A major problem involving comptroller personnel is the lack of experience, at base level, to budget for incentive contracts in military construction projects. This may require further training and education among comptroller personnel.

Another problem involves the disposition of the savings from FPI contracts. The Congress specifically authorizes and appropriates funds at a certain level for specific construction contracts. The Air Force should ensure provisions are made to allow it to use any excess funds (from potential project underruns) to pay for another project's modifications or cost overruns. This problem differs from other procurement activities due to the sensitivity of construction project approval and scrutiny by the Congress. For example, the comptroller can authorize the expenditures of excess operations and maintenance funds in such diverse areas as supplies, travel, or contract services. The expenditure of military construction fund is not as flexible.

Incentive contract use does not seem to alarm the director of the Air Force's military construction budget. The director thought FPI contract use would not alter their budgeting, obligation, and accounting for military construction funds since they frequently reprogram funds between construction projects between MAJCOMs with little opposition from the Congress.[14] The Congress concentrates on the approval of facility projects, not reprogramming funds.

6.2.1.4 STAFF JUDGE ADVOCATE GENERAL

Under an FPI contract, firms might argue about the actual costs they incur that affect their contract payments. The firm may try to justify certain costs that allow it to increase its firm's payment. This may require a legal interpretation or action on the Air Force's part if the firm sues the Air Force over the cost determination. The Air Force's judge advocate general, the legal arm of the Air Force (and similar

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14. Interview with the Director, Budget Investment (Assistant for Military Construction), 25 Sep 1991.

service legal agencies) would get more involved with contracting activities in this case.

Although the government faces the potential threat of more litigation, this may not be true. The firm can sue the government to change payments. Currently, the PCO can deny any firm's claims. The firm can appeal its claim in federal court. However, according to the Office of the Staff Judge Advocate of the Air Force's Contract Litigation Division, the amount of litigation may be lower under an FPI contract than an FFP contract.[15] Incentive contracts are more flexible in their payments and the firms may not be motivated to sue. If the firm overruns its bid, it will receive some cost subsidy for the overrun by the government. Firms have to litigate all claims under FFP contracts to seek more payments or they have to modify the contract.

Conversely, under an FFP contract any contract modification comes under intense scrutiny by the judge advocate general and other actors. This scrutiny may identify and stop questionable payments.

6.2.1.5 CIVIL ENGINEERS

Civil engineers also have a role in incentive contract use. Under an FFP contract, contracting officers use a civil engineer developed cost estimate to determine if the bids are excessively high, and if the project should be awarded to a small, disadvantaged business. Under an FPI contract, the civil engineers need to determine a range of estimated costs to determine an optimal α and expected contract payment. This may require a review and analysis of cost estimation techniques and relationships to ensure the estimate is accurate.

Typically, civil engineers develop a single cost estimate for construction project costs.[16] The civil engineers need to develop a range of estimated project costs to allow the PCO to calculate c_h and c_l. The

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15. Interview with the Director of Civil Law and Litigation, 21 Jun 1990.
16. Interview with the Office of the Civil Engineer and the Air Force Engineering and Services Center, 21 Jun 1990.

civil engineers may need more training to estimate ranges of estimated costs instead of a single cost estimate. This also requires a change in the current computer software.

6.1.1.6 OTHER SERVICES

Besides the Air Force, incentive contracts affect the Army and the Navy. The Army and Navy normally manage most of the actual construction and contract award activities of the project. These services do have to consult with the Air Force on the contract strategy for its projects.[17] If the COE and NAVFAC oppose the use of FPI contracts, this may create a conflict.

The COE contract management hierarchy was not aware of many cases of non-FFP contracts on construction and were hesitant toward accepting the use of FPI contracts in construction.[18] Their experience with construction contracts involved mostly FFP contracts and only a very few cost reimbursement contracts. This may have created an air of hesitancy about incentive contracting use due to the lack of experience of successful FPI contract use in military construction.

During World War II several COE contracting officers believed and advocated that the Army should use a contract having aspects similar to a CPFF and an FFP contract in some situations; essentially, they wanted to use an FPI type contract.[19] These contracting officers recommended its use in projects involving "risky" projects, like utilities projects, that involve the use of new construction techniques or technology.

Another reason the COE contracting management personnel seems hesitant to recommend incentive contracts was the determination of a proper α. The COE contracting officers were not even aware of the joint DoD and NASA Incentive Contract Guide that provides guidance to estimate

17. See Department of the Air Force 1955(d), AFR 88-3 New Construction, para 5(d).
18. Interview with the Corps of Engineers, 17 Jul 1990.
19. See Fine and Remington, The Corps of Engineers: Construction in the United States, p. 564.

an α.[20] This method calculates share rates that do not depend on the number of bidders, their expected costs, project types, or other variables. Many contracting officers at the Pentagon, MAJCOMs, and base level also were not aware of this guide for contracting work.

The NAVFAC, like the COE, also contracts for Air Force construction projects. The Navy seemed more enthusiastic about the potential use of contracts other than FFP contracts. They have used fixed price award fee contracts for facility remodeling and military family housing rehabilitation projects in the past.[21] Under this contract type, the contracting officer awards a minimum fee and can increase the fee based on a government panel's subjective fee appraisal of the firm's project quality. The NAVFAC Pacific Division did not receive any firm protests or complaints when they converted FFP contracts to fixed price award fee contracts for facility remodeling projects; apparently, these firms understood the Navy would subjectively determine their fee. The Air Force defines this contract type as a form of an incentive contract for construction projects.[22] The Navy uses this contract type to persuade firms to improve quality or another intangible performance factor on its construction jobs.

6.2.1.7 THE SMALL BUSINESS ADMINISTRATION

The Small Business Administration (SBA) also plays a major part in any attempt to implement the use of incentive contracts for military construction. The majority of contracts awarded in military construction are under the authority of the SBA (72 percent of all competed and sole source contract awards and about 50 percent of all contract dollars). The

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20. See Department of the Air Force 1969(a), Incentive Contracting Guide, p. 72.
21. Interview with the Navy Facility and Engineering Command's Pacific Division, 17 Sep 1990.
22. See Department of the Air Force 1989(i), United States Air Force Project Manager's Guide For Design and Construction, p. 2-14.

major concern by the SBA is the requirement for a firm to establish an accounting system to allow the DCAA to audit costs.

Contracting officers from all services and the SBA voiced concern about small and disadvantaged firms not having an extensive accounting system that meets DCAA accounting standards for incentive contracts. These contracting officers all say that the burden of maintaining the standard cost accounting system used by the DCAA is very expensive, and that this could raise firms' costs and contract payments.

However, the issue concerning the cost accounting system is not insurmountable. The DCAA does not require SBA contract awarded firms to maintain a government approved standard accounting system. They do require firms to maintain one if the contract value is over $10 million (in fact, many non-SBA awarded military construction contracts have values less than this threshold).[23] A DCAA official suggested that a less expensive, modified cost accounting system for SBA awards could allow he DCAA to determine actual costs. This system would not require much eff for the firm since it would follow commercial accounting practices and use standard Internal Revenue Service depreciation procedures.

6.2.2 PRIVATE ACTORS

Implementation of incentive contracts not only affects government operations, but changes private firm behavior. Two major groups from private industry that bear the greatest impact are the Associated General Contractors of America (AGC) and individual private construction firms.

6.2.2.1 THE AGC

The AGC provides a lobbying effort to represent the interests of private construction firms to the Congress and the DoD. The AGC opposes

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23. See Defense Contract Audit Agency, <u>DCAA Contract Audit Manual</u>, Sec 8-103 and FAR, Sec. 30.301(b3).

anything but openly competitive, FFP contracts.[24] It also does not support 8(d) awards. They believe a firm should bear all cost responsibility for a project.

The AGC has advocated the use of FFP contracts since World War II.[25] They believe an FFP contract award is cheaper for the federal government, simpler to award, and easier to bid on than other contract types. During World War II the Army experimented with construction contracts that used negotiations with firms to select the lowest cost contractor instead of a first price sealed bid award. The AGC successfully pressed local congressmen and the COE to return to FFP contracts with first price sealed bid awards.[26]

The interviewed AGC representatives in the national and local chapter offices also oppose the idea of using SBA awards. These representatives told me they felt that the construction industry has excess capacity and the federal government should openly compete all contracts among all qualified firms. They also mentioned that SBA eligible firms do not need special consideration and if those firms cannot compete openly, they should leave the industry.

The AGC does not have any experience with the use of incentive contracts. The representatives I interviewed were not sure how an FPI contract calculates a contract payment and did not have any idea under what conditions the Air Force could apply the FPI contract to military construction projects. They told me that since the federal government has used FFP contracts for decades, it does not need any changes.

6.2.2.2 PRIVATE FIRMS

Private firms face many potential changes in contract strategy and behavior if the Air Force switches to incentive contracts in its military

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24. Interview with the Associated General Contractors of America, 18 Jul 1990.
25. Interview with the Associated General Contractors of America, 18 Jul 1990.
26. See Fine and Remington, The Corps of Engineers: Construction in the United States, p. 577.

construction program. The firms may not understand how the share rate works or the implications for risk sharing inherent in the FPI contract. If a firm does not understand how an α value will affect its possible payments, this may affect its behavior. Also, the firms may not be comfortable with reporting actual costs to the DCAA. The firm also needs to develop a DCAA acceptable cost accounting system.

Some commercial construction firms have used FPI contracts in the past with much success.[27] These firms told me that FPI contracts can save money and that their contractors did not have any problems understanding the terms or conditions of the contracts once the firms receive an adequate explanation of the contract. Unlike the federal government, private firms can select specific firms and directly negotiate with them. The contracting officer, normally, cannot negotiate with individual firms competing for military construction awards.

The Business Roundtable, an association of large US corporations interested in many business topics (including construction) recommends that firms use incentive contracts in construction.[28] The Business Roundtable found that most construction jobs operate at extremes. Either the construction firm assumes all risks (FFP contracts) or the firm hiring a construction firm assumes the overrun risk (cost reimbursement contracts).[29] Their study found that owners (firms that hire construction firms) should develop a mixed strategy between these two extremes by using incentive contracts. The study estimates that using an FFP contract instead of an FPI contract could increase costs up to 5 percent.[30]

6.3 GOVERNMENT ACTIONS TO EASE FPI CONTRACT APPLICATION

In order for the Air Force to use the FPI contract in military construction, it must consider taking certain actions to implement this

27. Interviews with Bechtel and Fluor Corporations.
28. See Business Roundtable 1982(a), Contractual Arrangement Report A-7, p. 11.
29. Ibid, p. 16.
30. See Business Roundtable 1983(b), More Construction for the Money, p. 58.

contracting change. Some of these changes do not require much effort, while others may require substantial adjustments by individuals and organizations. In this section, I discuss some of the changes that the federal government can implement now to prepare the military construction community to accept and implement FPI contracts. These changes involve regulations, education and training, and cost accounting systems.

6.3.1 REGULATIONS

The first required change in Air Force military construction contracting procurement regulations involves the use of FPI contracts in all types of military construction situations. Many civil engineers and construction contracting officers refer to such documents as the USAF Project Manager's Guide for Design and Construction for military construction contracting guidance. According to this document, before an Air Force contracting officer can use a contract other than an FFP or fixed price award fee contract, he must get approval from HQ USAF/CE, or higher approval. This stipulation includes the FPI contract.

Many interviewed contracting officers said they did not want the attention or want to take the effort to use FPI contracts under this system. They regard the use of incentive contracts as a "risky" proposition to "buck" the system. Allowing the contracting officers more flexibility to use the FPI contracts, without HQ USAF/CE approval, can reduce a big obstacle toward implementing the use of incentive contracts. Similar guidance in the COE and NAVFAC can allow more latitude to contracting officers to use different contract types as well.

If this system is not changed, approvals from HQ USAF to use FPI contracts also will require a huge investment of contracting officer time and effort. Contracting officers may not be able to award properly, monitor, or administer other contracts because FPI contracts reduce the available working time. This process can significantly slow down scheduled project completions on other contracts, which can result in complaints from the contracting officer's superior and affect the contracting officer's career.

Contracting officers work in an environment that stresses the use of regulations and standard operating procedures over individual initiative. These contracting officers rely on written instructions, policies, and regulations to conduct their contracting activities. Thus, contracting officers operate in an organizational environment similar to Graham Allison's Model II organization.[31] In this case, the procurement organization relies primarily on using regulations and written policies that promote FFP contracts. According to Allison, standard operating procedures (SOPs) provide well established and understood rules of behavior for these organizations.[32] These SOPs, in the form of the FAR and civil engineering contracting policy, define the behavior of individuals within the organization. Perhaps the Air Force can revise the appropriate regulations and SOPs. In the long run, according to Allison, the organization's output (i.e., FPI contract use) can be best influenced by changing SOPs.[33]

6.3.2 EDUCATION AND TRAINING

The federal government contracting officer, comptroller, and civil engineering personnel will need more education and training. Also, civilian firms require education about the FPI contract.

Base level contracting officers will need to improve their skills to estimate optimal α values. Unless the contracting officer can successfully calculate this α, the incentive contract may not produce optimal savings rates. This skill takes time and practice, not just formal training courses.

For Air Force contracting officers, a prime source to provide initial and continuing education concerning contracting comes from the Air Training Command (ATC) and the Air Force Institute of Technology's (AFIT) School of Systems and Logistics. ATC provides courses in basic and staff officer level contracting that all Air Force contracting offi ers must

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31. See Allison, Essence of Decision, p. 67.
32. Ibid, p. 68.
33. Ibid, p. 256.

attend. AFIT provides refresher courses in residence and at various locations around the world and a correspondence course that covers several topics involving contract administration.[34] ATC and AFIT could revise their courses to reflect more emphasis on FPI contracts.

Another source of education, at a higher level, involves the education of acquisition managers and contracting officers at the Defense Systems Management College (DSMC). The DSMC provides courses on contract management and administration to potential program managers concerning major weapon systems acquisitions. However, many of these weapon systems programs involve facility construction. DSMC could show how the application of incentive contracting to construction can potentially reduce payments for future projects.

Additionally, the federal government may need to revise requirements for new contracting officers (military or civilian) that includes certain prerequisites. To become an entry level contracting officer, an applicant must possess a bachelor's degree. The Air Force prefers a specialization in business administration, industrial management, or industrial engineering, but this requirement is not mandatory.[35] Since the model in this study assumes some familiarity in statistics, one should consider this requirement. In fact, a DSMC instructor said that many students do not take his incentive contracting class due to its math content, which is finding the slope of a linear function.

One way to alleviate this problem is to require additional mathematical prerequisites to become a contracting officer. The Air Force could increase its entry requirements for contracting officers or add a more rigorous mathematical curriculum to its training. The Air Force also can require more math or quantitative methods refresher courses for current contracting officers.

Another change is to educate contracting officers to read and understand cost reports from the DCAA (or AFAA). Many contracting

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34. See Air Force Institute of Technology 1990(b), "School of Civil Engineering and Services," p. 11.
35. See Department of the Air Force 1990(g), Curriculum Policy Guide, p. 12.

officers administer FFP contracts and may not know how to interpret cost audit reports. These reports may help a contracting officer to avoid cost overruns and other potential problems. The government can use cost analysis courses to help these contracting officers read and properly analyze DCAA cost reports.

The Air Force also can revise the ATC and AFIT courses for the comptroller and civil engineering personnel. The comptroller personnel can receive additional courses in how to budget for incentive contracts at base level. Additionally, the civil engineers could get more training on advanced cost estimation techniques to improve their estimates.

Educating civilian firms on incentive contracts is also important. Frequently, the SBA and DoD offer seminars and conferences to the public on how firms can sell their products to the government. The federal government also prepares documents to help a firm sell products and services to selected agencies (e.g., Selling to the Military).[36] Additionally, when the Air Force prepares to solicit bids from firms on construction projects it prepares a bid package that includes bidding information and special contract clauses. Contracting officers could add an explanation about incentive contracting for the prospective bidders.

6.3.3. COST ACCOUNTING SYSTEMS

The DCAA should start the design of a modified cost accounting system for 8(d) awards. Though the DCAA may require less stringent cost accounting system standards for many SBA firms, the PCO still needs validated costs to decide final payments. As discussed earlier, the DCAA could implement a modified cost accounting system that should provide enough data for the ACO to process progress payments and PCO to determine a final payment.[37]

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36. See Department of Defense 1990(c), Selling to the Military.
37. Interview with the Director, Air Force Contract Administration Division and the Defense Contract Audit Agency, 18 Jul 1991.

Many interviewed 8(d) firms admitted that they did not keep accurate cost data for most of their projects (military or civilian).[38] An organized cost accounting system may indirectly benefit these firms by forcing these firms to evaluate financial decisions based on more accurate information from their current activities. This could help the firms streamline their businesses and become more competitive and efficient.

6.4 IMPLICATIONS OF FPI CONTRACT USE

If the Air Force uses the FPI contract, the federal government may face some difficult contracting issues. In this section, I discuss these implications and how they might affect the contracting activities in the government and private industry. These issues include: the application of FPI contracts in other organizations; the increased use of FPI contracts in private industry; the application to other types of procurement; more competition between firms; lower firm profitability under FPI contracts; and reduced labor and material costs.

6.4.1 APPLICATION TO OTHER ORGANIZATIONS

If the Air Force applies the FPI contract to military construction, other federal agencies might try to lower their payments on construction projects by using FPI contracts. The federal government agencies, other than the DoD, that spend the most money on construction activities include the Department of Transportation, the Department of Energy, and the National Aeronautics and Space Administration (NASA).[39] The Department of Transportation provides billions of dollars for highway and other

38. I interviewed about 24 8(d) military construction contract awardees from September 1990 to December 1990 that admitted that their cost accounting system had problems.
39. See Office of Management and Budget 1989(a), 1990(b), and 1991(c), Budget of the United States Government, various pages.

transportation construction, but it frequently gives funds directly to states in the form of grants and trusts to build and contract for the projects. The Department of Energy and NASA build test laboratories and facilities to house high technology systems.

Not all federal agencies may have the experience to apply successfully the FPI contract. Although the DoD and NASA have not used FPI contracts in military construction in the past, they have used FPI contracts in other projects. The two agencies have experience with the use of FPI contracts in many situations involving the production of many products like aircraft, space boosters, and satellite systems. In contrast, many contracting officers from other agencies were not familiar to FPI contracts. I talked to the General Services Administration, the Department of Transportation, the Tennessee Valley Authority, and the Department of Veteran's Affairs to get their views on incentive contracts. Each contracting officer mentioned that all their current construction awards were FFP contracts. Some of these contracting officers told me they knew about FPI contracts, but that they did not use them in any of their current contracts.

These non-DoD and NASA contracting officers may not know how to apply the incentive contracts. If they attempt to award an FPI contract, they may award contracts with a non-optimal α value. They also may not have the capability to audit costs or administer the contract. This may result in contract delays and litigation.

6.4.2 SPREADING THE USE OF FPI CONTRACTS

If the Air Force can demonstrate that it can successfully reduce payments in the military construction area, firms might try to use FPI contracts with their subcontractors. The federal government cannot require a firm using subcontracts to manage the activities of its subcontractors in a particular manner. If the firm improperly uses an FPI contract, the subcontractor can default on the contract, sue the firm, or delay contract completion. This can delay the overall completion of the construction contract.

If firms plan to use FPI contracts, they must investigate how they can successfully apply the contract like the Air Force. Unlike the Air Force, the firms can directly negotiate with bidders and usually do not use first price sealed bid award methods, which can affect the determination of an α value. Any miscalculation of α and subsequent adverse reaction by subcontractors to the FPI contract can affect the firm's future acceptance of the Air Force's offered FPI contracts. This can result in firms pressing their local congressional representatives and the AGC lobbying government officials to stop the use of FPI contracts.

If the federal government decides to use incentive contracts for construction, other levels of government might use this contract type as well. State and local governments frequently use FFP contracts or similar contracting strategies used by the federal government. These governments could view the use of FPI contracts for construction as a potential approach for their highway, facilities, and other public works projects. Since the federal government funds much of these efforts, it also might encourage states and local governments to use FPI contracts to reduce expected contract payments.

6.4.3 APPLICATION TO OTHER TYPES OF PROCUREMENT

Federal government contracting officers could use FPI contracts on projects that have characteristics like military construction. Many contracting officers use military construction as the quintessential project type in which the federal government should only use FFP contracts. If substantial savings are possible from the use of FPI contracts on these construction contracts, then contracting officers might use these contracts on other projects. This could increase the use of FPI contract types to projects where the government once used FFP or cost reimbursement contracts.

The federal government contracting officers could most successfully use FPI contracts on projects that have few bidders or wide cost ranges. These projects may have relatively firm specifications and requirements,

but the firms may not have the experience to make a product for a fixed price.

The DoD does use FPI contracts in the initial stages of production of aircraft systems such as the F-16 Fighting Falcon.[40] The Navy also uses FPI contracts in ship construction and overhaul. However, acquisition programs other than weapon systems rarely involve this contract type. The Air Force could identify other projects for which FPI contracts may seem more desirable than a cost reimbursement or FFP contract. These ideas may lead to the greater use of FPI contracts throughout the DoD and federal government.

6.4.4 INCREASED COMPETITION

Many economists support the concept of competition and encourage the federal government to expand its use in the determination of contract awards. The use of FPI contracts may increase the number of firms bidding on the contract (perhaps risk averse firms that would not enter the competition for the contract award, under an FFP contract, would bid under a safer FPI contract, which may result in some unexpected effects. For example, competition can make firms more innovative. Increased competition also may cause firms to commit fraud.

Competition indirectly forces firms to become more innovative in terms of production management or cost reduction efforts. For example, under the bid competition effect, low cost firms must find some way to lower their bids in order to win the contract award. These low cost firms may try new methods of construction for facilities or attempt to perfect ways to substitute less costly techniques for construction.

Competition, however, also creates some adverse effects among firms. To win a contract award, the firm may grossly overstate its ability to build a facility under cost, ahead of schedule, and in excess of technical specifications. The firms may try to submit fraudulent billings or use

40. See Bodilly, Camm, and Pei, <u>Analysis of Air Force Aircraft Multiyear Procurements with Implications for the B-2</u>, p. 30.

lower quality materials and bill the Air Force for high quality (and higher priced) materials to get reimbursed. The firms may feel that they could increase their profit by submitting cost padded bills and getting a partial reimbursement. The DCAA and contracting officer must be able to identify these overcharges.

6.4.5 REDUCED PROFITABILITY

The McAfee and McMillan model of FPI contracts in military construction shows that the Air Force could save money. This reduces profits for IFB contract award firms; but more importantly, it can affect the acceptance of the contract by many small, disadvantaged businesses. Reducing the profits for these small, disadvantaged businesses may force some of these firms to leave the industry or curtail their business activities with the federal government. The government may want to retain these minority- or woman-owned firms in the industry for social reasons.

These reductions in profits (with decreased risk of cost overruns for the firms), especially for the small businesses, may affect the use of FPI contracts. This is especially true during times of economic downturn when some economists may view the use of government expenditures as a stimulus to the economy. The Congress may want the Air Force to use FFP contracts in a depressed economy to stimulate the construction industry and save jobs despite the higher expected payments.

This concern brings up a broader question about the social benefit of contracting out construction work to small businesses. Earlier, I discussed the difference in payments between 8(a), 8(d), and IFB awards compared to the government cost estimates. Bids are higher for 8(a) and 8(d) awards than bids for IFB awards relative to government cost estimates. One must ask if the federal government believes this effort is worth the additional cost to the DoD to support these small, disadvantaged businesses. Apparently, the federal government does want to help small businesses even at the cost of spending additional funds. The government may need to reevaluate procurement goals and policies.

6.5 SUMMARY

The federal government can take several actions to implement the FPI contract in the military construction program. The government should consider how to select the particular contract scheme to apply the FPI; how contract changes to the present FFP contract scheme will affect certain actors; what actions it can take now to ease FPI contract implementation; and various implications that arise from the increased use of FPI contracts.

The Air Force can apply the FPI contract to military construction using several approaches. The Air Force should take a two step approach. In the short run, it can use a single optimal α value derived from maximizing savings per project type. This selected α value is designed to minimize expected contract payments by project type. In the long run, the Air Force can develop the appropriate procedures and software to calculate individual α values per project, like the McAfee and McMillan model.

Government and private actors are affected by the use of FPI contracts. The main actor in the federal government is the contracting officer. The federal government has to convince and properly train the contracting officers to accept and award FPI contracts since these individuals must administer the contracts. However, the government must consider other governmental actors that include auditors, comptrollers, staff judge advocate generals, civil engineers, members of other services, and the Small Business Administration.

In order to ease the implementation of the FPI contract, the government can take certain actions now. The federal government can modify certain acquisition regulations and policies to allow contracting officers to use FPI contracts on military construction projects. Contracting officers and private firms also would benefit from improved education and training about the use of FPI contracts. This allows them to understand how the FPI contract works and how they might calculate an α value. Additionally, the DCAA can modify cost accounting systems to

ensure the government and private industry can fairly determine costs in order to calculate final payments.

The use of FPI contracts also results in certain implications for the federal government. If the Air Force can save money on its military construction program, other federal agencies and private industry might increase their use of the FPI contract. The success of FPI contracts on military construction projects also may spread its use to other types of procurement. The increased use of FPI contracts can lead to increased competition and will reduce profitability among firms. The government must decide whether the reduction in profits for certain construction firms, due to the FPI contract, is worth the savings from these contracts. The federal government must especially weigh the effect of FPI contracts on 8(d) award firms.

APPENDIX 6.1

In this appendix, I explore whether an FFP contract provides a higher level of profit for a firm than under an FPI contract. Though an FPI contract benefits the Air Force by reducing its estimated contract payment, not all firms may accept this contract type. I assume a firm acts to maximize its expected utility ($EU(\pi_i)$). A method to determine whether a firm might oppose FPI contract implementation involves the calculation of the amount of π_i each firm might receive under each contract type. I assume the firms are risk neutral.

The firm's π_i is:

$$\pi_i = (1 - \alpha)(b_i - C) \qquad \text{(A6.1.1)}$$

I can redefine the firm's π_i (from Chapter IV equation (7)) as:

$$\pi_i = (1 - \alpha)(b_i - c^*_i - \omega) + (1 - \alpha)\varepsilon_i - h(\varepsilon_i). \qquad \text{(A6.1.2)}$$

The firm lacks control over ω. Earlier, I assume the $F(\omega)$ follows a normal distribution and $E(\omega) = 0$. I also assume that firms base their bids on the assumption that $E(\omega) = 0$. Therefore, I do not consider ω in this discussion.

The firm's π_i is:

$$\pi_i = (1 - \alpha)(b_i - c^*_i) + k_i. \qquad \text{(A6.1.3)}$$

I define $k_i = \left((1-\alpha)(\varepsilon_i) - h(\varepsilon_i)\right)$.

The firm bids b_i, where $b_i > c^*_i$.

The McAfee and McMillan assume a bid function (with a uniform probability density function) of:[1]

$$b_i = \frac{(c_h - c^*_i)}{n} + c^*_i$$

$$= \frac{c_h}{n} + \frac{(n - 1)}{n}(c^*_i). \qquad (A6.1.4)$$

I can now substitute A(6.1.4) into (A6.1.3) to simplify the value of π_i. This results in:

$$\pi_i = (1 - \alpha)\left(\frac{(c_h - c^*_i)}{n} + c^*_i - c^*_i\right) + k_i$$

$$=(1- \alpha)\left(\frac{(c_h - c^*_i)}{n}\right) + k_i. \qquad (A6.1.5)$$

Suppose the firm now bids for the contract award using (A6.1.4). It needs to know the number of bidders, n, the upper range of expected costs, c_h, and its expected cost, c^+_i.

From (A6.1.5), it is claimed that the firm's profit is maximized at $\alpha = 0$. Therefore, firms would prefer an FFP contract, not an FPI contract (if firms are risk neutral). If a contracting officer offers $0 < \alpha < 1$, this reduces the firm's $E(\pi_i)$. $EU(\pi_i)$ does not necessarily decrease, since the risk of a cost overrun is

[1]See McAfee and McMillan 1985(b), Incentives in Government Contracting, p. 4-24.

reduced. If firms are risk neutral, then $EU = E(\pi_i)$ and firms prefer $\alpha = 0$. If the firms are risk averse, $\frac{dE(\pi_i)}{d\alpha} < 0$, but the contract is less risky, so the effect on firm utility is ambiguous.

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